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Report of the Federal Government on Research 1996

Abridged Version

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REPORT OF THE FEDERAL GOVERNMENT ON RESEARCH 1996

— ABRIDGED VERSION —

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Foreword

What course is needed to lead Germany into a successful future? – There is no other question today that is so much in the focus of political debate and that is gaining more public attention. The labour market situation in particular calls for fundamental changes. The consolidation of public budgets and affordability of social security systems need to go hand in hand with a thrust for a change in economic structures, creating new growth and hence new jobs. In the final analysis, it will be our capacity for innovation, our will to change, our creativity and skills to develop new solutions that will decide on whether we can make a fresh start, whether Germany will resolutely seize its opportunities in international competition.

Innovation is not a one-dimensional process. Its success depends on many factors such as a conducive legal framework, available capital, entrepreneurial risk, predictable market opportunities and especially on knowledge and its accumulation, the skills and commitment of the labour force as well as competence in research and development.

Research and development are moving into the centre of the Federal Government's policy which aims to make the future possible. With its 1996 Report on Research the Federal Government takes stock of the situation of research in Germany and at the same time tries to outline important future development strategies.

This Report intends to be more than a snapshot. It documents the development of research in Germany, looks at it in an international comparison and derives options for research policy.

One conclusion in particular moves into focus: The crucial challenge for the future is to make better use of the outstanding potential of research in Germany and increase its importance for the development of the state, of society and the economy. In view of the necessity for public budgets to exercise spending discipline and of stagnating expenditure on research and development in the business enterprise sector – even though some industries increased their commitment considerably – the central task is to achieve better cooperation between science and industry as a whole. This applies especially to those areas which are of strategic importance for Germany's international competitiveness, for innovations in manufacturing and services, for improved preventive health care and better environmental protection. The relative decline in R&D expenditure in Germany is a danger signal which nobody can fail to see. So the conclusion to be drawn is that we have to pool and optimise our resources to make Germany a place which, based on top-level research, openness for innovation and open-mindedness in cooperation, offers new development possibilities for technology-based businesses in particular.

The Report on Research is not only addressed to experts, but also to the general public. For efficient research needs not only a favourable setting to be created by the government, but also support and encouragement by the public. What people think up at their desks and develop in laboratories is too important for our country to be known only to the expert community. Research is everybody's business. This is why I wish and hope that the Federal Government's Report on Research will not only find many readers, but will also meet with a wide response and that it will help rouse recognition and new enthusiasm for the opportunities that researchers open up for us through their commitment and achievements.

Dr. Jürgen Rüttgers
Federal Minister of Education, Science, Research and Technology

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"To make the future possible" is the categorical imperative of the outgoing century. It is not a philosophical construct, but a political programme, the response to the triple challenge that Germany is facing at the threshold to the next millennium:

- Germany's internal unity needs to grow. The development process in Germany's new Länder (states) is pushing ahead. Today these states are one of the dynamic growth regions in Europe. Nevertheless it will be necessary to continue to assist and support the change in economic structures. The more swiftly this process is implemented, the faster development opportunities will turn into a thrust for economic innovation and growth in the whole of Germany and the faster additional latitude will be created for the necessary curtailment of government tasks and expenditure.
- Geo-economic change – the growth dynamics of technology-driven newly industrialised countries (NICs), especially in Asia-Pacific, and of reform states in Central and Eastern Europe, the permeability and integration of the markets, the globalisation of enterprises (global sourcing) as well as the increasing mobility of knowledge, capital and products – has a direct impact on Germany. The competition of companies has now been joined by a competition of locations ("Standorte") in which Germany must hold its own. In view of more than 4 million unemployed the traditional structures of industry, society and the state need to be renewed. Demographic development and changes in the population's working behaviour increase the pressure on labour market structures and social security systems to adjust.
- The geopolitical changes of the 1990s brought Germany new international responsibility. But this responsibility can only be a shared European responsibility. Building the EU and European unification will always be pivotal points in German policy. In this process Germany as a leading industrialised nation is called upon to contribute to solving urgent global problems such as the rapid growth of the world's population, the threat to ecological systems as well as the vicious circle of poverty, hunger and disease.

Politics, industry and society are equally challenged by these problems. The Federal Government is banking on a broad-based alliance for the future. Its foundations were laid in talks between the Chancellor and top representatives of industry and trade unions. Concrete decisions are needed to attain the shared objective of creating more than 2 million additional jobs in Germany by the year 2000.

With its Action Programme for Investment and Employment the Federal Government is making a major contribution towards achieving this aim. Reducing the burden on enterprises and private incomes by cutting taxes and levies not only ensures employment, but also creates latitude for investment in the future, for new areas of growth and hence new jobs.

Growth and employment for tomorrow cannot be achieved with yesterday's knowledge and processes. What is needed is a new dynamism of development, is shaping the future with an open mind and with the courage to introduce changes. This process will be based on people's skills and creativity, on the progress of scientific knowledge as well as on technological performance and the capacity for innovation.

Education and science, research and technology have thus become the focus of a policy which aims to make the future possible. At a time when the knowledge available world-wide doubles every five to seven years, when every workday about 5,000 scientific papers are published round the world, science has become the most important – albeit varied and short-lived – "raw material". The transition from the industrial age to the information age is a reflection of this development which indeed marks the beginning of a new era.

"Unlike the traditional form of knowledge which is described as broken down into disciplines, as academic, homogeneous and passed on in books, the present form of knowledge is characterised as context-based, transdisciplinary, structured as a dialogue and variably available in different media" (Wolfgang Frühwald). Technical and scientific knowledge in particular needs to be generated today bearing in mind its envisaged application and contribution to problem solving. Innovations will have a greater chance of success if potential users can be involved in devising R&D activities with a view to future market potential; this calls for interdisciplinary cooperation in research and development. Research as a node in the interactive knowledge system of modern societies is thus gaining additional importance. Openness, interaction and processability of research are crucial to the ability of modern societies to learn and hence to develop.

As a result, the expectations to be met by research today are high. Of course, nobody can fail to recognise the hazards spawned by modern science-driven technological development itself. But the ability to detect developmental errors and their causes and to identify possible solutions is again also the result of exploration and recognition. To understand the interdependencies and conditions of our existence and to disclose the implications of our actions or omissions is the most prominent task of research and as such it shapes the self-image of the humanities and increasingly also of natural and engineering sciences.

The Federal Government places great emphasis on the importance of research for the survival of our polity. Safeguarding our natural resources in the long term, structural change in industry through innova-

tion, responsible guidance of the multimedia revolution while safeguarding its authenticity, open-mindedness and intellectual acuity as the fundamentals of cultural vitality, creating a new balance between individualisation and social cohesion – these are the challenges where research is making a crucial contribution. This is why it is one of the principal tasks of politics to promote and encourage research and safeguard its freedom and room for development. It is from this perception that the Federal Government derives the central objectives of its research policy:

– *Promotion of high technologies as drivers of innovation*

Due to their cross-disciplinary nature high technologies such as information technology and biotechnology offer a high innovation potential. The recent report on Germany's technological performance (see Part II, Section 11) made it quite clear that German industry is running the risk of not taking proper advantage of this potential. Often the link between science and industry is not close and fruitful enough to enable industry to develop systematic, knowledge-based and fundamental innovations.

As German industry is coming under increasing international competitive pressure in the field of advanced technology products, the high-technology base is still too narrow, but this is exactly where markets with the greatest growth potential will develop in the future. Even though German science is generating international top results in many areas, e.g. in molecular biology, microsystems or plasma technology, their implementation usually takes too long.

This is why it is an important objective of the Federal Governments's research and technology policy to develop high technologies and ensure that they are quickly implemented in promising areas of application, not least in the service sector. More than ever before, Germany has to become a high-tech country to broaden the basis of its economic power.

– *Innovation-oriented research policy*

The innovative capability of our polity has become a key issue. Whether we will be able to ensure lasting material prosperity, employment, social and ecological security in this country will in the final analysis depend on how we manage to adapt to new challenges and create new basic conditions for industry and society.

In this situation a research and technology policy plays a key role which does not restrict itself to providing an efficient research infrastructure, but takes account of the necessary feedback between research, development, innovation and dissemination as well of the integration of various policy areas that have an impact on innovation. Hence research and technology policy is called upon to make a major contribution to a dynamic innovative and economic system by offering an intelligent mixture of promoting and funding research in the classic manner, stimulating exchange processes between science and industry and creating a general setting that is conducive to innovation. Adaptability and openness for change in businesses, research institutions and other players involved are increasingly determining the ranking of national innovation systems.

The Federal Government therefore considers research and technology policy an integral part of a broad-based general policy which is conducive to innovation and aims to improve cooperation between industry and science and further the development of favourable basic conditions and cooperative networks within the innovation system. With the Council for Research, Technology and Innovation to the Chancellor a platform was created which focuses the dialogue between science, industry, associations and politics on central issues of our future. The recommendations of the Council call upon all those involved to help support and implement innovations on their own initiative and responsibility.

In a market economy system, enterprises in particular are the chief players in the innovation process. But it is absolutely crucial for the innovative strength of companies that the mutual transfer and feedback processes between basic research and application-oriented research and development in industry work satisfactorily and that technology is disseminated to a large group of businesses. In this context small and medium-sized enterprises (SMEs) play an important role because, due to their flexibility and quick responsiveness as well as the fact that they are technology users, they contribute significantly towards technological change. The Federal Government is giving high priority to supporting these small and medium-sized enterprises. This is why better access for SMEs to the venture-capital market and to the results of research and development as well as more favourable conditions for setting up new companies and hiving off units into independent operations, especially technology-based firms, are among the focal points of this integrated policy approach.

– *Cultural vitality and performance*

Science is an integral part of our culture and the sciences shape and mould the cultural development in Germany with a lasting effect. Science and research are among the sources that nourish our intellectual life. Cultural wealth and the intellectual climate are not least reflections of scientific development.

The Federal Government's research policy is guided by this role of science and research which is of central importance for the creative abilities of our polity. It highlights the significance of the humanities and social sciences and supports their dialogue with the natural sciences to further a better

understanding of the complexity of human action and its underlying motivation.

Many of the central questions raised by modern social development cannot be answered by science and technology; on the contrary – it is the pace and depth of scientific and technological development that bring up the question of the value-based coordinate system of society and its directive influence on personal action. Science that faces the question about its ethical basis and limits makes an important contribution to laying normative foundations.

The dialogue between science and society is indispensable. Science must "meddle", it must raise its voice in public. The Federal Ministry of Education, Science, Research and Technology (BMBF) will intensify its support of this dialogue by organising events and issuing publications focusing on questions about our future, thus contributing to a better acceptance of new technologies and developments in our society.

– *Research to provide for and shape the future*

Social and cultural changes are among the great challenges of the future. Demographic shifts alter the face of society. Family life and familial organisation have changed in Germany as well as in other Western industrialised nations. The trend towards individualisation and pluralisation corresponds with changing values.

To further our understanding of our natural and sociocultural resources and to analyse and prospectively assess our actions are among the central tasks of science and research. They create the vital basis that we need to find answers to the urgent questions of our time – the unemployment crisis, the environmental hazards, the emergence of new diseases and the dissolution of social relationships resulting in growing deprivation. None of the global dangers can be defused without scientific and technological progress, either. The interaction of demographic growth, energy consumption and pollution of the atmosphere alone shows that scientific and technological progress opens up opportunities for sustainable development.

The Federal Government has given high priority to supporting research into future needs and implementing its results. This is why, among other things, it will

- present a new energy research programme designed to achieve the Federal Governments's objective of reducing CO_2 emissions by 25 % through tapping additional energy conservation potentials and supporting renewable energies and their commercial use;
- develop a new environmental research programme aiming in particular at investigating ecosystems and the conditions of their preservation and development based on the principle of sustainability as well as working towards the further development of environmental protection technologies andproduction-integrated environmental protection with a view to improving the process of protecting the environment in terms of both cost-effectiveness and economic competitiveness;
- develop a new concept of mobility to ensure optimum mobility through intelligent transport networks, at the same time substantially reducing resource consumption and environmental pollution.

– *Safeguarding and improving scientific excellence*

In international competition Germany's scientific excellence is an important advantage, while its traditional reputation as a leading science nation is at the same time an obligation. To ensure the excellence of research institutions and their staff and to promote young scientists is therefore the main yardstick and mandate of research and education policy. The basis of that policy is the constitutional freedom of science. Consequently, the Federal Government places great emphasis on the self-government of scientific organisations. The constitutionally guaranteed freedom entails the obligation to ensure a maximum of scientific excellence and responsibility. The Federal Government expects science and research to meet this challenge on a permanent basis. Competition ensures a high level of research. Hence it is all the more important to base government funding in the various areas on rules of competition and performance criteria inherent in science. The Federal Government supports the Science Council with the intention to ensure a high research standard by evaluating research areas and institutions.

– *Strengthening and networking the research system*

The scope of the research system and the fact that different tasks are accomplished by science organisations and research institutions are among the strengths of the German science system. To ensure this system's future dynamic development is one of the main tasks of the Federal Government's research policy. The Federal Government has substantially increased the funds appropriated for research and development in the BMBF budget, thus underscoring its intention to step up investment in research and development in spite of the need to cut public expenditure.

By increasing the funds budgeted for the German Research Foundation and the Max Planck Society in 1995 and 1996 by 5 % the Federal Government has confirmed the importance of basic research as an element of government provision for the future. The universities offer an ideal setting for transdisciplinary research which is gaining in importance because it is at the interfaces between the various fields of research that significant breakthroughs and innovations are achieved. But too little use is being made of this offer. For this reason the Federal

Government aims to strengthen research in the higher education sector. This can be achieved through reforms within higher education institutions, e.g. in allocating funds or by introducing independent research activities for young scientists. At the same time it is necessary to improve the dovetailing of basic research and application-oriented research and to translate scientific results into innovative applications. Research needs patience and endurance. Technology-oriented research relies on broad basic research. They represent two sides of the same coin. But it is imperative to strengthen interfaces and junctions. The trend in industry to withdraw from long-term research needs to be reversed. Researchers and their institutions, in turn, have to show the highest possible degree of openness and flexibility. The Federal Government will improve the general setting required to achieve this end. In consultation with the Hermann von Helmholtz Association of German Research Centres (HGF) it intends to make the excellent know-how and potential of the national research centres available for wider commercial use.

– *Developing the research system in Germany's new Länder (states)*

For many people German unity has become a fact of everyday life. On the one hand, this is an encouraging sign. On the other hand, the challenges and also the opportunities arising from the development of the new Länder are anything but workday routine. To realise these opportunities a concerted effort by all those concerned will still be needed in the future.

Science and research now have the opportunity to tap a larger source of knowledge, experience and talent. The necessary basis has already been created. The reorganisation, development and renewal of universities and non-university research institutions have made considerable progress. Related to population figures, the research capacity of institutions receiving basic funding in the new states is by now equivalent to that in the old Länder. The funds expended per employee are even considerably higher than in the old Länder. All in all, about 50 universities, institutions of higher education and Fachhochschulen as well as more than 140 non-university institutions contribute towards a balanced density of institutions. These figures do not include additional institutes that the Max Planck Society intends to set up.

The BMBF allocates a total of about DM'3 billion to education and research in the new Länder. As far as industry-related R&D capacities are concerned, the worst is likely to be over and capacity reduction has reached a standstill. But productivity, R&D expenditure and export rates which are still low compared with West German companies call for further innovative adjustment. The Federal Government will therefore continue its commitment to strengthening industry-related R&D capacities; but the share of total funding allocated to the new Länder will increase.

– *Acceptance and freedom of research*

Research can only flourish in a climate of general open-mindedness. Surveys have shown that in Germany research and technology actually meet with a high level of acceptance. But this acceptance is not without criticism. Research and technology are welcomed as drivers of progress, but at the same time critical questions are asked about the possible negative impact of new technological developments.

The Federal Government advocates an open discussion of the opportunities and risks of technological developments. Impact assessments reflect a responsible attitude which requires openness and freedom from prejudice as well as an awareness of the ethical limits of what is feasible. But the Federal Government firmly rejects any attempt to hinder research and technological development by unfair means.

Freedom and responsibility of science and research are mutually conditional. To call for scientific freedom means to protect the constitutionally guaranteed room for development. This also includes the self-organisation of science and its financial security as well as the prevention or curtailment of regulations and inequitable restrictions caused by legal provisions or administrative enforcement. This is why the Federal Government, together with representatives of science and industry, is systematically reviewing regulations and procedures to find out whether they restrict or hinder research activities. Wherever possible, restrictive regulations will be corrected.

– *Internationality and international cooperation*

Internationality has always been an integral part of the self-image of science and it is now becoming more and more important in the international competition in which science and industry of the various countries and regions are engaging. Germany needs to remain open and become attractive again so that the best brains world-wide and with them top-level know-how can be drawn into this country.

The Federal Government therefore promotes the internationalisation of the German research system. Universities and non-university research institutions alike need to enhance their international attraction and design the services they offer in such a way that more foreign students and young scientists find their way to Germany. This will provide the long-term basis for a wide variety of links in both science and industry on which Germany as an exporting country depends.

In view of the markets of the future and the body of knowledge required for far-reaching innovations research and technology policy without international cooperation would not only be a torso, it would also result in the inefficient use of limited national resources. To be launched fundamental innovations need international standards; they are developed increasingly in an environment of glob-

al industrial cooperation as well as in a feedback process with nationally and internationally generated basic knowledge. To avoid misuse and to limit potential negative consequences new technologies need to be the subject of international regulations and agreements. For global environmental protection projects as well as for climate, polar and marine research programmes it is obvious anyway that knowledge and resources need to be pooled across national borders. High costs and investment risks alone make it increasingly difficult for individual countries to realise large-scale research plans and implement costly technology projects on their own, e.g. in the fields of space flight, high-energy physics or astronomy.

For this reason the Federal Government invests in European and world-wide cooperation. In addition to the well-established European, transatlantic and German-Israeli partnerships which will be developed further, special attention is given to scientific and technological cooperation with the fast developing industrialised and newly industrialised countries in Asia and South America as well as with Central and East European countries and the successor states of the former Soviet Union which are going through a difficult transformation process. In the years to come the BMBF will try to take advantage of the opportunities arising from its cooperation experience with important countries which in some cases dates back more than 20 years. The concept for scientific and technical cooperation with Asia-Pacific was published in October 1995, a Latin America concept is in the process of being drafted (cf. Part V, Section 2.1.2).

2. Challenges for research and technology in the 21st century

Research policy as an integral part of an overall policy designed to provide for the future has to face up to the challenges with which Germany is confronted at the threshold to the 21st century. Meeting these challenges means banking on the opportunities offered by science and research.

2.1 Globalisation

Economic interdependence

Due to declining transport and communications cost as well as changed patterns of generating value added the importance of geographical distances is rapidly diminishing. Capital, technological know-how and labour are becoming increasingly mobile and are looking world-wide for locations that are best suited to meet their requirements. So the competition of companies for market shares and technological leadership has now been joined by a competition of locations for research and production capacities.

As a result of the strong growth world-wide of direct investment and capital links in the 1980s the global economy has assumed a new character. Value added is increasingly generated in multinational enterprises with world-wide links. A major part of world trade transactions is conducted among affiliated companies across national borders (one-third of US exports takes place within multinational companies). Germany is intensively involved in an ever more sophisticated international division of labour. The Deutsches Institut für Wirtschaftsforschung, DIW (German Institute for Economic Research) has established that 21.9 % of the employees of German companies in the manufacturing sector work abroad*). In 1977 this figure had only been 13.6 %. However, foreign direct investment in Germany is stagnating; in the same period the percentage of employees of foreign subsidiaries in the total number of employees in the manufacturing sector dropped from 17.1 % to 16.2 %.

Among the forces driving this increasing globalisation are the progress achieved in information and communications technologies, an improved transport infrastructure, the deregulation of trade, services and capital markets at multilateral and regional levels as well as the participation of dynamic countries in Asia, Latin America and Eastern Europe in the international division of labour.

There is also a certain increase in regional trade links which are more and more supported by regional intergovernmental agreements. In the course of intensified European integration and the further development of the single market in Western Europe the share of intraregional commodity trade in total commodity trade rose from about 65 % in 1983 to just under 70 % in 1993. Asia boasts an ever higher increase in intraregional trade flows from about 43 % (1983) to nearly 59 % (1993). The main reason for this development is the persistent dynamism of growth in that region.

Globalisation offers companies the opportunity to optimise the procurement of bought-in materials and services (cost optimisation through global sourcing), in some cases this is done by hiving off certain production areas into independent operations. The diversification of production sites, more market presence and greater customer focus, the attempt to evade protectionist trends in newly emerging large economic areas, the short time available for the exclusive marketing of new products, exchange risks and stronger competitive pressure from new competitors and newly industrialised countries are the decisive motives of many businesses to establish footholds world-wide.

In most multinational companies R&D activities are still mainly performed in the home country; but this tie is becoming less and less strong. Even "sensitive" technologies which largely used to be reserved for the research capacities "at home" are increasingly handled abroad. In most cases the internationalisation of R&D activities is not based on a decision relat-

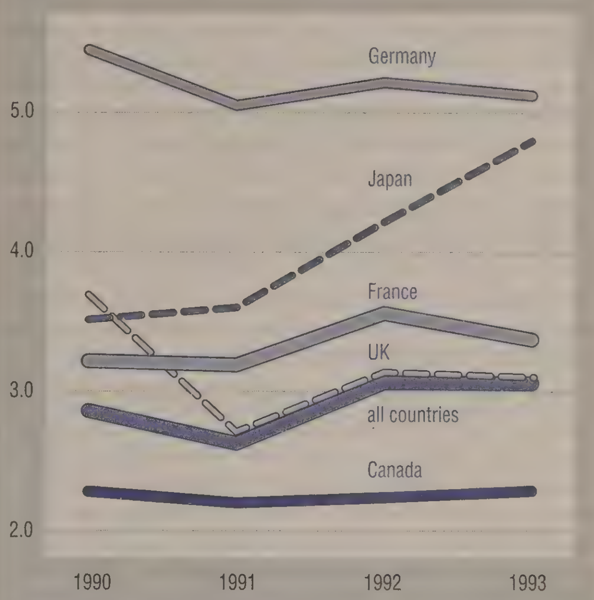
*) "Germany's Technological Performance", background-material to the report on behalf of the Federal Ministry of Education, Science, Research and Technology; study by the Deutsches Institut für Wirtschaftsforschung (DIW), Bonn 1996, p. 63.

ed exclusively to research and development. Recent analyses suggest the following main reasons for going global:

- When a foreign company is bought its research facilities and research staff are taken over as well (direct investment). The associated acquisition of know-how may well be the main motive, but it may also be market access via the distribution channels, brand name and range of goods and/or services of the company purchased.
- Creation of own research capacities in a centre of excellence that is leading world-wide in order to participate in top-level research. In addition to the regional market potential the research environment of the new location will also gain in importance.
- Presence in a "lead market", i.e. where an innovative high-quality product will quickly be in demand. Special standards in a particular country, e.g. in environmental protection, may also be a decisive factor in those cases where development activities are closely linked to production.
- R&D cost may also play a role, e.g. low labour or laboratory costs for development tasks and, to a lesser extent, also for research functions. This is an area where newly industrialised countries with "islands" of excellent research may gain in importance in the future.

Figure I/1

R&D expenditure as a share of gross output of US subsidiaries abroud – Total business enterprise sector –
- in % -



Source: US Department of Commerce, DIW/ZEW Calculations 1995 BMBF, BuFo '96

Like direct investment statistics a complete survey of the R&D activities of German companies holding participating interests abroad is not yet available. But some countries (USA, UK, France, Japan) have provided information on the R&D expenditure by companies in which foreigners hold participating interests. Based on these data the R&D expenditure by German companies abroad in 1993 can be estimated at about 15 % of the R&D expenditure of the business enterprise sector in Germany (based on purchasing power parity). In the chemical and pharmaceutical industries which have the highest level of internationalisation this figure is just under 30 %. According to various analyses, the percentage of patent applications filed by German companies where the invention was made outside Germany was between 11 % (European Patent Office) and 15 % (US Patent Office) in the late 1980s. Patent data thus are additional proof of the fact that the share of research in German companies based abroad was correctly estimated to be around 15 %.

Internationally, Germany continues to be regarded as an attractive country to conduct research in. In terms of the number of research-performing companies with Japanese equity participation Germany ranks second after the UK in the list of European research countries. Germany has the highest percentage of manufacturing Japanese subsidiaries performing their own research and development. US subsidiaries in Germany have the highest foreign R&D potential, followed by companies with Swiss majority interest. About 25 % of the total R&D expenditure by US subsidiaries abroad is accounted for by Germany which – from the US perspective – has thus been leading the list of research locations for quite some time. Foreign subsidiaries in Germany have spent more than DM 7 billion on research and development, employing more than 34,000 people (full-time equivalent)[1]). This means that about 15 % of the R&D personnel in the business enterprise sector works for subsidiaries of foreign companies. This more or less equals the share of manpower working in these subsidiaries in the total number of persons employed in the business enterprise sector. In 1993 foreign companies held a share of nearly 16 % in total business enterprise expenditure on R&D in Germany. At just under 15 %, the corresponding percentage in the USA and France was slightly lower, the UK rate, at 26 %, was clearly higher and in Japan this percentage amounted to only 5 %. This clearly demonstrates that research and development in the German business enterprise sector have a relatively high level of internationalisation.

Hence Germany has excellent opportunities to hold its own in the overall trend towards globalisation, provided the factors important for international competitiveness can be strengthened to avoid or reverse a negative balance when qualified jobs are shifted. As well as the cost issue and the speedy development of the communications infrastructure, these factors include internationally attractive top-level science and research as a basis for the technological performance of German industry. It is only when these requirements are met that employment can increase again in the manufacturing and service sectors (cf. Part II, Section 9.3).

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[1]) This includes only that percentage of the universities' total expenditure that is spent on R&D (basic funds for research and development as well as external funds).

Demographic development

One of the greatest global challenges is the rapid growth of the world's population. In 1960 only about 3 billion people were living on this planet. By mid-1995 there were about 5.75 billion. Every year the world population grows by more than 86 million people. Taking the mean value of several forecasts, there will presumably be about 10 billion people on this Earth by the year 2050. Today 79 % of the people is living in developing countries. Almost the entire future population growth will take place in Asia, Africa and Latin America, more than half of it in Africa and South Asia. In contrast, the European share will drop from currently nearly 13 % to just under 7 %.

Even today abject poverty is the bitter fate of 1.3 billion people, 800 million suffer from malnutrition, 600 million are unemployed and 1 billion illiterate.

It is in the poorest countries in particular that the exodus from the rural areas to the cities continues. The cities can no longer absorb the influx. Labour market and infrastructure cannot cope either. In many big cities more than half of the population live in slums where poor living conditions spawn delinquency and diseases. So far only about 35 % of the population in the developing countries lives in cities, compared with approximately 75 % in the industrialised nations. But while in 1950 only two out of eight cities with more than 5 million inhabitants were situated in developing countries, it is today nearly 30 out of a total of about 40 of such mega-cities.

Apart from poverty and lack of opportunities, wars and ethnic conflicts are the causes of major migration and flight movements. In 1994 the United Nations High Commissioner for Refugees in Geneva registered over 24 million refugees in more than 143 countries. As a result of the crisis in Bosnia the number of refugees soared in Europe as well and rose from 830,000 in 1990 to about 3 million in 1995.

For many developing countries rapid population growth is a factor which, together with other causes and conditions, boosts the interaction of poverty, malnutrition and destruction of the environment. These countries are confronted with the gigantic task to ensure adequate economic growth without overly exploiting natural resources.

At the International Conference on Population and Development held in Cairo in 1994 the member states of the United Nations drafted a joint action programme to meet these challenges. Industrialised countries like Germany are facing a dual task:

- They have to replace their own resource-intensive consumption and production patterns with a concept of prosperity that reduces the exploitation of resources.
- They have to support the developing countries on their way to sustainable development to ensure that even with a growing world population the viability of the ecosystem Earth will not be jeopardised.

In this context research and technology have a key role to play. To provide a rapidly growing world population with humane living conditions without destroying the ecological resources is a task that cannot be accomplished without far-reaching progress in science and research.

Global change

The changed view of the global problems of the 21st century focuses on the acceleration of environmental pollution and the great burden placed on ecological systems. The system Earth is subject to constant change; humanity as part of the living world has to take this change into account if it wants to act responsibly.

Human action has always affected natural cycles. But today these interferences have assumed a new dimension. As a result of industrialisation, higher mobility and an increasing demand for energy and food by a growing world population large areas of the earth's surface were transformed and global material cycles were altered. Consequently, the atmosphere and biosphere are being burdened with ever higher pollutant loads and the diversity of ecosystems and species is diminishing.

In the coastal areas climate factors, a rising sea level and storm floods may interact to amplify their individual effects. At the same time, these regions are among the most densely populated and most intensively used areas in the world. Two-thirds of humanity live at a maximum distance of 60 km from the coast. If the sea level rose by one meter on average, about 5 % of the world's population would be directly affected, e.g. by more extensive protection schemes, and in Europe it would even be 10 %.

Semi-arid areas cover one-third of the earth's land surface and are home to 20 % of the world's population. Even minor changes in the water balance could make agriculture and animal husbandry impossible in these regions. This holds for large areas in the tropics and subtropics; but there are also parts of Southern Europe where similar problems exist. It is estimated that by the year 2050 about 4 billion of the then almost 10 billion people will have to live in dire need, or with a shortage, of water.

Recent simulations with coupled ocean-atmosphere models confirm earlier estimates of global warming rates to be expected as a result of increasing greenhouse gas concentrations. According to the second status report published by the Intergovernmental Panel on Climate Change the mean global temperature will increase by about 2 C (band width 1–3.5 C) by the end of the next century unless emissions are reduced. This would be associated with a sea level rise of approximately 50 cm (band with 15 – 95 cm) by 2100. Based on this report it has to be assumed that man-made climate changes can already be identified today. Hence it is no longer a question of preventing climate change, but rather of reducing the substantial impact that is associated with uncontrolled emission development which affects e.g. human health and agricultural production, and it is equally important to adapt human activities to climate changes.

It was discovered in the 1980s that the stratospheric ozone layer over the poles was gradually depleted due to the formation of chlorine radicals from CFCs and that this might lead to an increase in UV radiation reaching the Earth's surface. Currently the global annual mean ozone concentration in the stratosphere is decreasing by 0.3 % per year. Since the late 1980s these strong negative trends – with seasonal variations – have also been observed over large parts of Europe.

Climate change caused by altered atmospheric trace gas concentrations and the effects of the ozone hole do not stop at national borders. This is why global change is a challenge that can only be met by international cooperation, i.e. joint political action. By pooling forces and competences at the international level research, science and technological innovation can and must provide the necessary systems knowledge and the technical tools to make preventive action possible.

2.2 Germany's technological performance in international comparison

Together with the USA and Japan Germany is one of the three greatest technology producers in the world. The high level of prosperity in our country is the result of industry's ability to continue to develop new products, to achieve rapid rises in productivity and constantly to improve quality. These factors will also determine the future scope for macroeconomic growth and the creation of qualified new jobs.

The drivers of technological change are those industrial and service sectors which make above-average investments in research and technology. A good 90 % of the total knowledge available in industry is concentrated on R&D-intensive sectors (where investment in research and development amounts to more than 3.5 % of turnover). A substantial part of the scientific and technological problem-solving skills of our society is concentrated in these sectors.

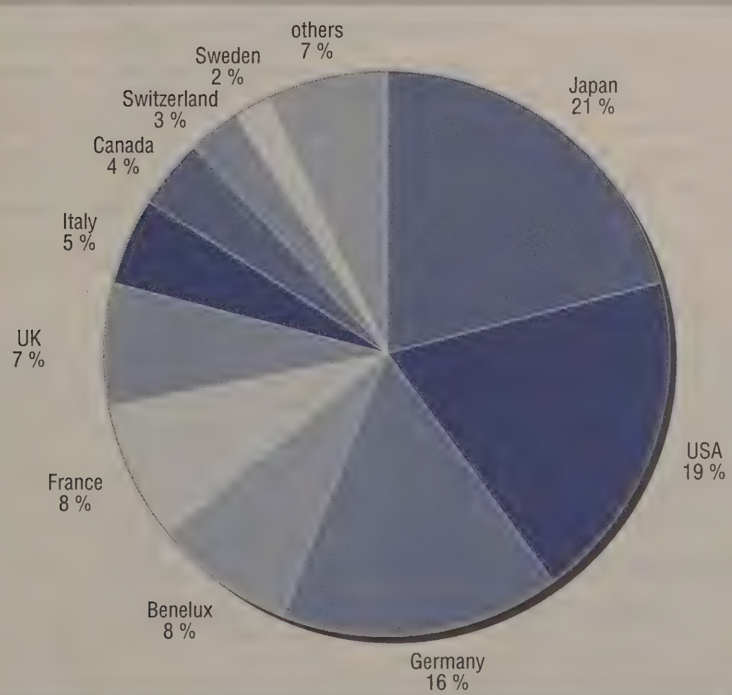
Since the late 1970s the R&D-intensive sector in Germany has continuously increased its share in industrial production in West Germany from about 42 % to approximately 45 %. Contrary to some misperceptions, the macroeconomic significance of industries which perform intensive research and development is higher in Germany with a 13.5 % share in GDP than in the USA (8.5 %) and equal to that of Japan (cf. Part II, Section 9).

In addition to the direct effects of research-intensive sectors of industry on economic growth and production the indirect effects are quite substantial. Structural change in industry has for quite some time favoured the service sector. In this process a capable and efficient research-intensive industry often serves as a catalyst. Services expand fastest where there is adequate demand from innovative industries. Many high-quality services are needed where research and development, marketing, financing and production take place. New technologies bring approaches to

Figure I/2

Foreign trade shares of OECD countries by R&D-intensive commodities 1993

in %



Source: OECD; Foreign Trade By Commodities; special evaluations; NIW calculations (December 1995)

BMBF, BuFo '96

solutions to existing service areas (e.g. software) which make it possible to generate new value added.

An analysis of long term development shows that research-intensive sectors in all OECD countries have made above-average contributions towards employment in the business enterprise sector. In Germany the increase in employment was considerably higher than the OECD average. But in spite of further gains in productivity a substantial number of jobs were shed in recent years even in these research-intensive sectors of industry. In Germany, however, this went hand in hand with a decline in business enterprise expenditure on R&D and weak investment activities. Whether the service sector and small and medium-sized companies in particular will be able to fulfil the hope for a substantial increase in employment in the years to come will probably also depend on a reversal of these trends.

Performance profile

In a setting of international division of labour national economies tend to specialise. They cannot all tap the innovation potential of every sector to the same extent which would not make any sense, anyway. Rather, main areas tend to develop in the various national economies which are based, among other things, on the respective industrial and scientific traditions and skills. In other areas national economies will adopt new technologies offered in the world market and combine them with their own knowledge. It is essential to take advantage of the benefits offered by the optimal integration of German industry into a scheme of international division of labour in the field of research and development.

Germany's technological performance is characterised by a very wide range of goods, multi-grade production involving a large number of small and medium-sized enterprises as well as a high level of training and technical know-how. Skilfully taking advantage of the international division of labour in research, German industry has used its traditional strengths in the areas of high-quality capital goods (machinery, vehicles), electrical engineering and chemicals. Based on relatively intensive R&D activities of its own and considerable technological diversity, it has repeatedly occupied dynamic market segments in these sectors. In this process high technologies and cross-disciplinary technologies were to a great extent integrated into traditional core areas. Especially R&D activities in the technical areas of new materials, software/simulation, flexible integrated manufacturing and environmental technologies are usually spread over several industrial sectors. In the years from 1991 to 1993, for instance, 58 % of R&D-performing companies in the manufacturing sector were involved in research and development for new materials. The relatively intensive implementation of high technologies explains the hitherto strong position in the markets for up-market commodities.

Challenges

Germany's technological specialisation, however, is not balanced. Technology management in German companies focuses on technological areas which still have a high rate of technical innovation in Germany, but lack dynamism at the global level. In addition, the technology portfolio in which German industry can maintain its world leadership position is becoming narrower. Too few novelties are developed in dynamic fields of technology.

- Since the 1980s Germany's deficit in invention and production activities has been growing in those product areas that are based on microelectronics (EDP facilities, semiconductor components, office machines, home electronics). This negative trend is reflected in patent specialisation which – with the exception of the Netherlands – is negative for all other European countries as well. Only the USA, Japan and the Netherlands concentrate an above-average proportion of their invention activities relevant for the world market on microelectronics-based products. In foreign trade Germany has a traditionally weak position in the entire information technology area. The market is clearly dominated by Japan (with a world trade share of 34 %) and the USA (22 %), while German commodities account for only 8 % of the world trade volume. The generally weak position of German suppliers, however, does not preclude a consolidation in individual market segments of information technology. Germany's position in measuring and control engineering is excellent. In the wake of the world-wide economic upturn for microelectronic components German industry, supported by government funds, could re-establish itself in this technology area. In the important growth markets for mobile radio, chip cards, communications technology as well as sophisticated standard and specialised software German industry also has a good international position. Opportunities for German industry are opening up in those markets where existing comprehensive systems knowledge can be fully brought to bear. This holds for complete systems solutions, automation technology, networking and modern multimedia technologies. Microsystems may bring about fundamental changes similar to those introduced by microelectronics in the 1980s.

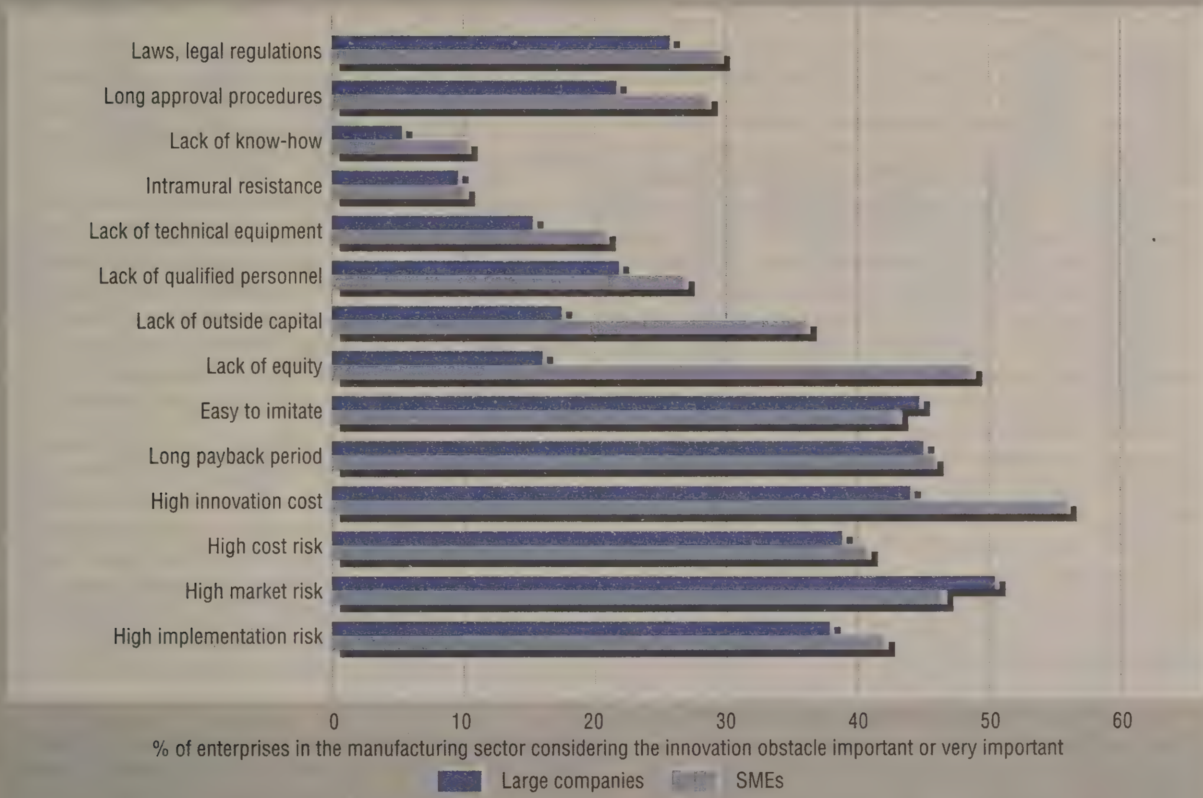
- The USA has taken the technological lead in biotechnology, as it did in microelectronics, and is now increasing its head start. In Germany, patent applications are filed for relatively few inventions, compared with the international situation; specialisation in biotechnology is still below average. In the next few years the fast development of biotechnology will put great pressure to substitute on established product lines in the chemical, pharmaceutical, food processing and crop protection industries, to mention but a few. With a share in world trade of nearly 18 % Germany is currently holding the leading market position for these products ahead of the USA. This is why German industry's future viability will be put to the test in biotechnology like in no other technological area.

Figure I/3

Ranking of innovation obstacles by business enterprises (1995)

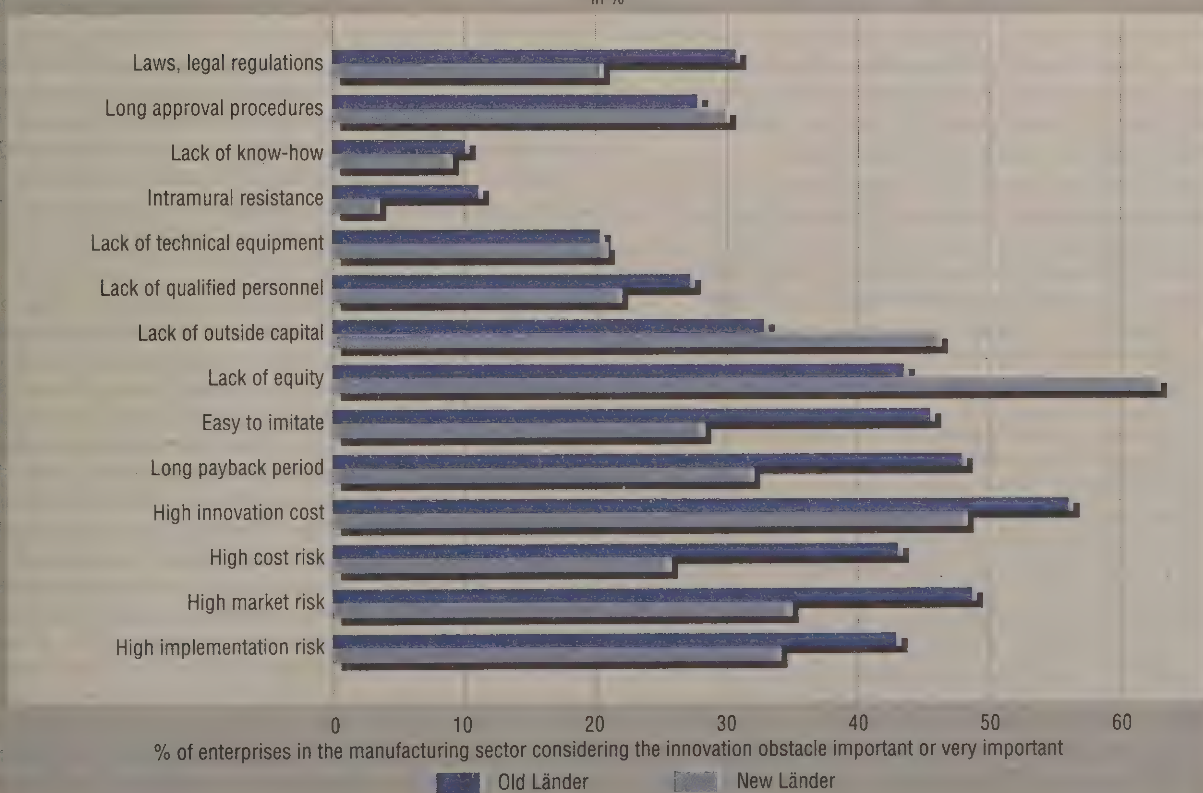
Comparison between small and medium-sized enterprises and large companies in West Germany

- in % -



Comparison of small and medium-sized enterprises in the old and new Länder

- in % -



Source: ZEW (1996); Mannheimer Innovationspanel

BMBF, BuFo '96

- Germany is still holding a strong position in environmental technology. In the world markets environmental technology products will become more and more important, a situation for which German industry is perfectly prepared. But Germany is no longer the largest exporter of products which might be used for environmental protection that it used to be in earlier years. Today it is the USA which is leading with a world market share of 19 % ahead of Germany (with just under 18.5 %) and Japan (13 %).
- Germany's still relatively stable position in the international markets relies on its pioneering role in technology in Europe which still secures large sales markets for this country. This statement has to be qualified, however, when it comes to direct relations with the most important overseas competitors, the USA and Japan. In recent years newly industrialised countries (NICs) in Asia as well as other emerging economies could strengthen their position in world-wide technology markets. Their present share in research-intensive imports of OECD countries amounts to about 16 % and is rising fast. There is much evidence suggesting that Japan is likely to come under special pressure by Asian NICs whose commodity range is very similar to that of Japan. Low-wage NICs do not yet have sophisticated product ranges in the mechanical engineering and vehicle construction industries, i.e. in product groups that are important for Germany. This situation may change as Southern and Central European countries which have a long-standing tradition in the capital goods sector are also developing their economies.

Expenditure on research and development

Germany is still enjoying a high level of research, development and production based on new technologies. But its lead has shrunk as others have caught up. The group of participants in the international technology competition has become larger as many small countries have joined the race.

Future markets will be conquered through investment in education, research and development as well as in plant and equipment. In simplified terms, research and development activities conducted in 1996 are aimed at the markets of the years 1999 to 2003. The decline in relative R&D expenditure in industry therefore casts a shadow on the picture of Germany's technological performance.

In Germany in 1994 the share of gross domestic expenditure on research and development in GDP was 2.33 % (after 2.43 % in 1993). So in that year Germany came fourth – though by a narrow margin – behind France among the G7 states and sixth among the OECD countries (with Sweden being first and Switzerland fourth). In 1994 total business enterprise expenditure on R&D had risen by only 0.8 %. Recent surveys conducted by SV-Wissenschaftsstatistik GmbH suggest a higher growth rate of about 2 % for 1995 (cf. Part II, Section 9.1).

In the 1980s the leading industrialised countries, with a 3 % share of GDP devoted to R&D, had reached a sort of sound barrier. In almost all national economies which perform research and development at top level the trend has taken a downward turn. This decline has to be seen against the backdrop of different development patterns. As early as the late 1980s industrial research in Germany had slackened; this was the sector which until that time had been the driving force behind the process of catching up with the leaders and whose contribution to R&D expenditure had been above average in international comparison. At the same time smaller countries were catching up in terms of R&D activities and in some areas are now already quite close to the big ones.

The first signs of the long-term effects of this low R&D profile which had already lasted quite some time were visible years ago in R&D output indicators such as patent data. Compared with the world-wide average the German patent position has deteriorated since the early 1990s; according to the most recent figures, however, the decline is no longer as sharp as it used to be at the beginning of the decade.

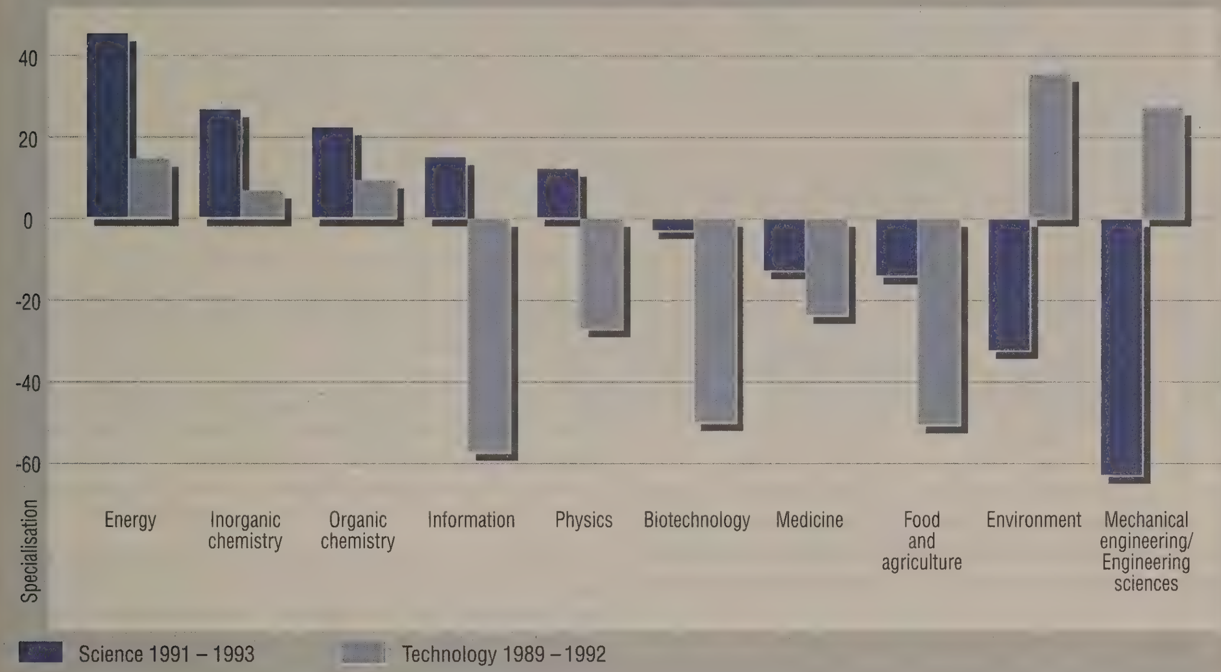
Industrial companies' restrained attitude towards innovative projects can be explained by a host of causes. R&D activities and innovations are high-risk investments. Company surveys have shown that corporate innovation potentials, know-how deficits or lack of external information on new technical solutions are not so much seen as obstacles to innovation. Much more often innovative projects are jeopardised by the high market risks of new products and services and a lack of venture capital.

Technology-based industries generate an above-average proportion of their turnover through exports. This is why they are particularly affected by the high external value of the Deutschmark which has further increased the cost pressure on innovative projects in international competition. For many companies investment in innovative projects with a long payback period has become a problem. As a result R&D expenditure was subjected to much more stringent cost and quality controlling. In small and medium-sized enterprises "soft" innovation barriers such as lack of access to risk capital, inflexible management structures and inadequate organisational structures impair the companies' ability to absorb knowledge and hence their capacity for innovation.

As well as the incremental changes which in the medium term make the greatest contribution towards the macroeconomic increase in production, developing the German technology potential is one of the most crucial tasks in the long term. Where innovation potentials diminish and the lead in innovation shrinks competition in terms of price and volume is becoming more important. When the effects of today's investment in research and development and real capital are projected onto potential macroeconomic results to be achieved in the years to come, the resulting scenario does not suggest a consolidation of technological performance in international comparison. For it cannot be assumed that the rules of the past will no longer be valid according to which the technological basis determines the economic structure, the comparative advantages as well as income and employment rate of highly developed national economies. This means

Figure I/4

Germany's scientific and technological specialisation by field of technology, 1989–1993[1)]



1) Share of scientific publications/patents using the international average as baseline (index = 0).

Source: SCI-ISSRN-database, EPO; ISI calculations

BMBF, BuFo '96

that for Germany as a high-wage country new latitude for growth needs to be generated through more – and not less – investment in the future.

2.3 Changes in the world of work

At present, more than 4 million people in Germany are unemployed. The number of jobs needed is estimated to amount to more than 5 million. This is why the central challenge for politics and science is to overcome the employment crisis and create new, stable jobs.

The causes of the current labour market development are complex. Both cyclical factors and long-term trends seem to be equally involved. Hence coping with unemployment is not only a quantitative problem of how to distribute work. Against the backdrop of structural changes the issue is turning more and more into a qualitative problem. As well as economic globalisation, the changing pattern of international division of labour and growing international pressure in terms of cost and competition, the transformation into a service society, the emergence of new patterns of work and workflows as a result of technological innovation, demographic developments and changes in people's work habits are other important characteristics of the changes in the working world.

Transformation into a service society

At the end of the last century nearly 50 % of the labour force was working in the primary sector. Today it is only 3 % (1.1 million). Over the last 20 years employment in the German industrial sector dropped by about 40 %. In the service sector, on the other hand, the number of employees has risen by a good 3.7 million since 1976. Also in the period from 1992 to 1994 the number of service jobs grew by 1 % per year, but this was not enough to make up fully for the loss of nearly 1.6 million jobs in the manufacturing sector.

While in 1985 – according to a study of the Ifo Institute – about 55 % of the labour force in Germany was working in the service sector, it was already approximately 60 % in 1993. New jobs were created above all in the health care, management consultancy, data processing and retail sectors. The dynamic development of business-related services in particular suggests that there is a strong interaction between the manufacturing and service sectors. Services as part of an industrial offer decide ever more often on that offer's global competitiveness. The contribution made to value added by services rendered in the manufacturing sector will continue to grow. According to a recent forecast 18.4 % of the labour force working in this sector will provide counselling and caring, education and publishing services by the year 2010, compared with only 11.8 % in 1991.

The extensive use of information technology and the transformation into an information society go hand in hand with a change in occupations and employment areas. Recent studies by the Institut für Arbeitsmarkt- und Berufsforschung (Institute for Labour Market and Occupational Research) show that over time the main working activities of people have shifted more and more towards handling and processing informa-

tion. When assigning people to occupations focusing on "information activities"it is possible to isolate a fourth sector "information" from the three traditional sectors of agriculture, manufacturing and services whose development can be described separately. According to this approach about 50 % of the total labour force in Germany have currently to be assigned to this "information" sector; in the year 2010 it will be approximately 55 %.

The contribution the service sector is making to the total employment figure and to the aggregate value added is increasing. The European Commission, for instance, expects that by the end of this decade 7 % of Community GNP will directly depend on the telecommunications sector, compared with 2 % in the 1980s. With nearly 100 million employees, a turnover of $ 2,000 billion and a contribution to global GNP of 5.5 %, the tourism industry is today already the largest sector of industry.

Compared with the USA, the service sector in Germany still seems to be capable of development. The table below gives a breakdown of the total labour force by the most important areas of the tertiary sector:

Percentages of total labour force, 1992

	Trade	Transport	Finance	Social services	Total
	– in % –				
Japan	21.5	7.1	9.7	23.1	61.4
Germany	15.3	6.2	8.1	29.0	58.6
USA	22.2	5.5	10.5	34.9	73.1

Source: Labour force statistics 1972–1992, OECD, Paris 1994

New patterns of work and workflows

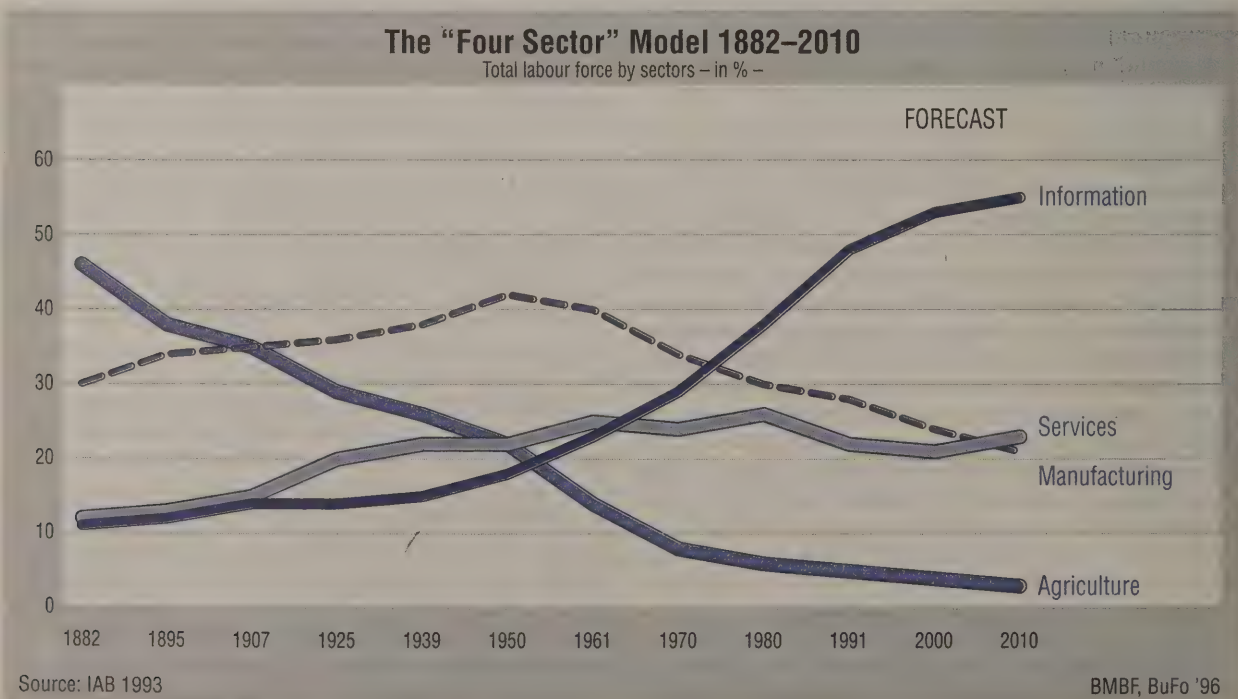
Development in the service sector is not least pushed by the new information technologies. Their dissemination in new areas of application will also change traditional patterns of work and workflows. The potential for flexibilisation is growing and will lead to more individualised working hours and job profiles. Former in-line workflows will increasingly be replaced by integral processes which will shorten development and production times. The possibilities opened up by telecooperation will broaden and accelerate this process.

Demographic development, work habits and labour market situation

In Germany, as in almost all major industrialised countries, a medium-term increase in the population's average age can be expected. Forecasts indicate that by the year 2030 a quarter of the population in the industrialised nations will be over 65.

Generative behaviour and an increasing life expectancy will in the long term lead to a shift in the ratio of economically active population to non-active population. IAB calculations suggest that assuming an unchanged labour force participation and a lack of immigration there will be almost 3.5 million fewer economically active persons in Germany by the year 2000 than there were in 1994. The percentage of under-30 year olds in the labour force will drop from currently about 30 % to approximately 20 % by the year 2030 in spite of the rising number of female and foreign workers. The average age of the labour force will increase. At the same time, the body of knowledge and hence the qualification requirements

Figure I/5



Telecooperation

"The massive use of information and communications technologies will change the contents and structures of work in many areas. The present structural change in the working world – which is characterised by decentralising corporate structures, focusing on core businesses accompanied by outsourcing, networking and abandoning conventional normal employment relationships – can be accelerated even more by the new technologies. In so-called virtual companies with a large number of contract workers businesses are interconnected via data networks and cooperate in temporary partnerships under changing company names. The cooperation of decentralised units (individual workplaces, units, entire plants, sectors of industry), especially in an international framework, will in many cases fundamentally restructure the division of labour as well as work links between groups of companies, businesses and operations. Consequently, not only traditional job descriptions may change, but also employment relationships and forms of corporate organisation as well as cooperative relationships and relationships of dependence between operations and companies. The impact on the employment relationship is ambivalent: On the one hand, work and individual plans for one's life can be better reconciled; on the other hand, employment relationships associated with a lack of legal security and quasi-self-employment may give rise to new dependencies which burden the labour force with unacceptable risks."

Source: Statements and recommendations by the Council for Research, Technology and Innovation, "Information society – opportunities, innovations and challenges", December 1995

change at ever shorter intervals. It is a crucial task for the future to ensure that our society whose age structure is changing radically will be able to generate an adequate innovation potential in science and industry. This is why in the process of work continuing education and personnel development are becoming more and more important.

Work habits reflect a general shift away from material to so-called post-material values (e.g. self-realisation, participation). The desire for more latitude to organise one's own life is becoming ever more important. In the world of work new expectations have emerged with regard to working conditions and work content. According to a recent poll, 38 % of respondents in this country can imagine themselves working in the leisure industry. In the age group of up to 29 years it is even a clear majority of 55 %. The change in expectations and demands is quite unequivocally reflected in the following results: 71 % of those willing to work in the leisure industry believe that in this way they can combine hobby and work. Potential earnings were important for only 57 %. The previously rigid borders

Potential of telework

"The definitions and interpretations of telework range from regular dependent work in a person's home environment using information and communications technologies to occasional information processing irrespective of the location to mobile work using electronic media which would also include the work of free-lancers and self-employed persons. Telework will establish itself side by side with traditional patterns of work and, depending on the industry concerned, it will be more or less sophisticated. If, in keeping with the vision described in the Bangemann Report, the number of teleworkers in the EU could be raised to about 2 million by the year 2000, Germany – according to its share in the EU population – would have 800,000 telework places.

In many cases telework will not move completely outside a plant or an office; depending on the respective needs and area of work temporary presence may be necessary. Polls have shown that part-time workers in particular and people who for various reasons would like greater flexibility in their working life are interested in the different forms of telework. For example, telework enables employees better to reconcile family and job. The time needed for commuting to the employer will become much shorter; it has to be taken into account, though, that only a small number of employees would like to do completely without a workplace at the office. Polls suggest that the banking and insurance industries, business-related service sectors and public administration are particularly suitable candidates for telework. The interest of decision-makers in telework increases as company size grows. At the business level productivity gains of up to 20 % as well as cost and time savings are expected which translate into higher competitiveness of the companies. In macroeconomic terms telework will lead to investments of several hundred million DM per year. It is estimated that the turnover of telework places will amount to more than DM 5 billion in the year 2000. Studies expect that with 800,000 teleworkers there is a savings potential of about 3.2 billion car kilometres per year."

Source: The Federal Government's report on "Info 2000 – Germany's on its way to the information society", 1996

between work on the one hand and leisure on the other are partly crumbling to make room for a more flexible transition from one area to the other.

New tasks for research

According to all studies conducted so far occupational activities will have to meet different and more stringent requirements to enable people to cope with structural change. The number of jobs for qualified skilled labour undergoing practice-oriented initial and continuing vocational training will continue to increase. The attributes of the labour force of the future are a high level of technical skills, initiative, willingness to take decisions and assume responsibility as well as the ability to communicate and work in a team. Group work and telework will help flatten hierarchies and delegate responsibility. Life-long learning will replace the traditional separation of training and work because only continuing education and training will enable the individual to adapt to changed requirements. It is the task of *vocational training research* to study these processes of change and develop adequate approaches to taking advantage of new technical possibilities.

As the structure of the world of work changes, careers and access to occupations and positions are being transformed as well. To analyse occupational changes and occupational mobility is one of the core tasks of future *occupational research.*

When resources are scarce, persistent major labour market problems call for instruments of labour market policy to be used in a particularly efficient manner. *Impact studies* will have to find action-oriented answers to questions about success control, qualitative and quantitative employment effects, implementation problems, costs of schemes and cost comparisons.

The newly founded Max Planck Institute for Demography in Rostock underscores the importance for research policy of the scientific search for answers to the challenges entailed by demographic change. The spectrum of approaches currently under discussion ranges from an extended working life to a specific integration policy to women's issues and family aspects.

The necessity of taking on competition in the national and international markets for technology-based products and production processes calls for the investigation of adaptation processes not only on the part of the workforce. Research in engineering, economic and social sciences also needs to focus on working conditions and working environments at the shopfloor and extra-plant levels with a view to designing work and technology in a more human-focused way. Improving health protection by reducing and averting health hazards at the workplace, ensuring the viability of services and developing strategies to cope with the effects of demographic change on future gainful employment are other important fields of action for the Federal Government.

3. Research as an integral part of the policy for the future

3.1 "Operation Research" – topography of the German research system

Structures of the German research funding system

The German research system and the interaction of the various partners – to simplify matters – can be broken down into R&D-performing and R&D-financing sectors. This structure – which is commonly applied to make international comparisons – may be used to describe the relationship between the sectors and their components as well as their development over time (cf. Part II, Figure II/3).

Performing research and development

The R&D-performing sectors in the Federal Republic of Germany are

- the higher education sector,
- the government and private non-profit sector, and
- the business enterprise sector.

The *higher education sector* includes universities, comprehensive universities and Fachhochschulen. Its share of R&D expenditure in the gross domestic expenditure on R&D in Germany currently amounts to about 19 % (1991: 16 %)[2]).

In this sector R&D expenditure is focusing on natural sciences (28 %) and medical sciences (26 %). Engineering sciences as well as the humanities and social sciences, with 19 % each, hold equal shares, while agronomy has a relatively low share (5 %).

Research in the higher education sector receives substantial funds from the German Research Foundation (DFG), its largest provider of external funds.

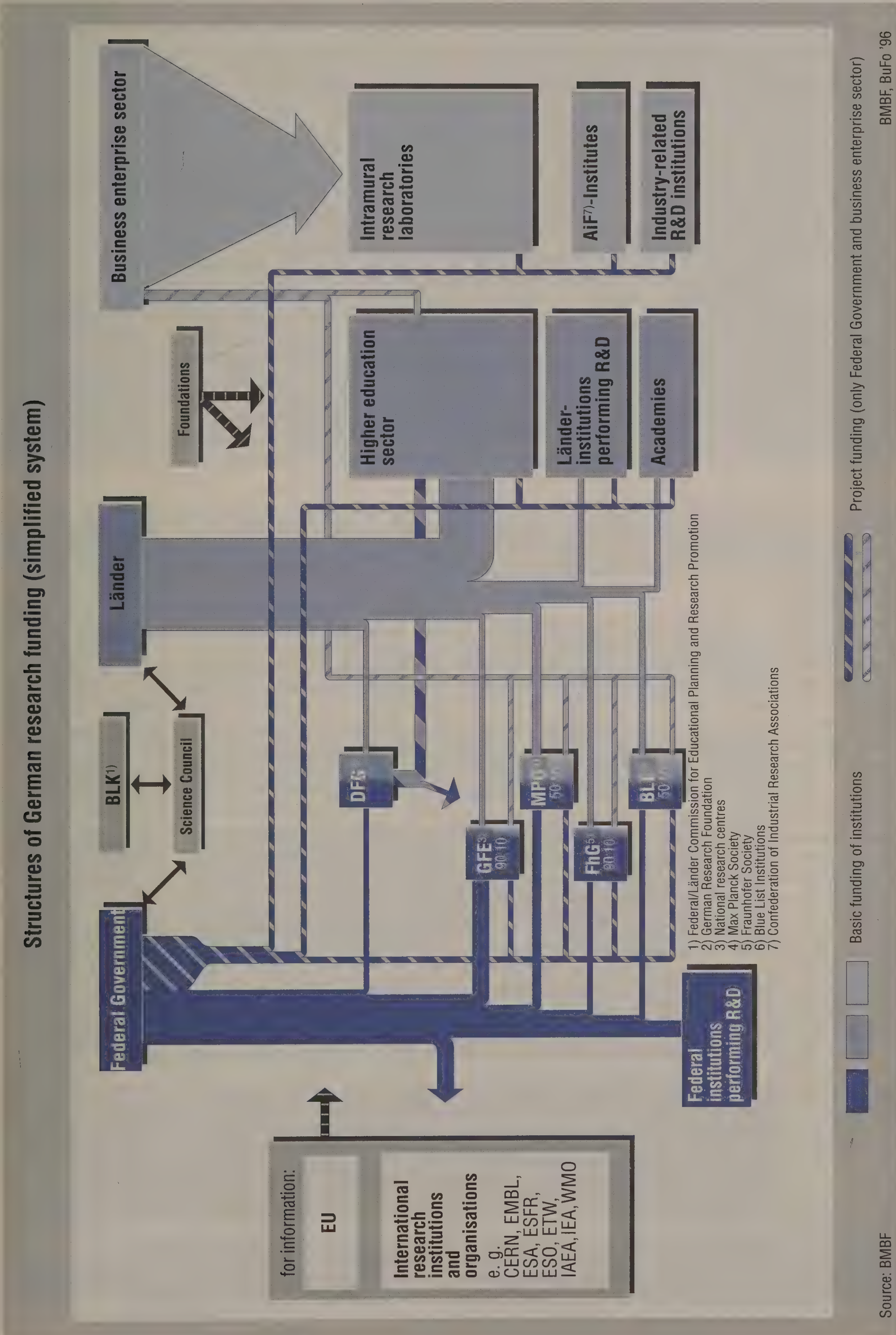
The *government and private non-profit sector* encompasses research institutions owned by the Federal, Länder and local governments, such as federal and Länder institutions with research functions. They perform research tasks which contribute considerably to fulfilling the departmental functions of the various ministries, e.g. in the areas of agriculture, health, environment, materials, raw materials and metrology as well as defence.

This sector also covers private non-profit organisations, i.e. the national research centres, the institutes of the Max Planck Society (MPG) and the Fraunhofer Society (FhG), research institutions included in the Blue List, the Academies of Sciences as well as other private research institutions. It also includes scientific museums, libraries and archives which – to a variable extent – also perform research and development[3]). At

[2]) This includes only that percentage of the universities' total expenditure that is spent on R&D (basic funds for research and development as well as external funds).

[3]) The research budget includes only that percentage of the institutions' resources that is spent on R&D.

Figure I/6


Structures of German research funding (simplified system)
Business enterprise sector
Foundations
Länder
BLK[1)]
Science Council
Federal Government
Intramural research laboratories
AiF[7)]-Institutes
Industry-related R&D institutions
Higher education sector
Länder-institutions performing R&D
Academies
DFG[2)]
MPG[4)] 50 : 50
BLI[6)] 50 : 50
GFE[3)] 90 : 10
FhG[5)] 90 : 10
Federal institutions performing R&D
for information:
EU
International research institutions and organisations
e. g. CERN, EMBL, ESA, ESFR, ESO, ETW, IAEA, IEA, WMO
1) Federal/Länder Commission for Educational Planning and Research Promotion
2) German Research Foundation
3) National research centres
4) Max Planck Society
5) Fraunhofer Society
6) Blue List Institutions
7) Confederation of Industrial Research Associations
Basic funding of institutions
Project funding (only Federal Government and business enterprise sector)
Source: BMBF
BMBF, BuFo '96

Research funding in the business enterprise sector

Beyond research activities in its own research facilities industry has taken numerous funding initiatives which contribute to the success of Germany's research and innovation system.

Confederation of Industrial Research Associations (AiF)

Supported by funds provided by the Federal Ministry of Economics (BMWi) the AiF finances cooperative industrial research; its membership includes more than 100 research associations. One of its main objectives is to compensate for the structural disadvantages of small and medium-sized enterprises. Since SMEs cannot afford to maintain their own research facilities cooperative industrial research offers them the opportunity to make use of research results and thus boost their innovative strength.

Foundations

Foundations hold a prominent position among the initiatives taken by industry to promote and fund science and research. The *Donors' Association for the Promotion of Sciences and Humanities in Germany,* for example, a joint exercise by industry, supports science and technology in research and education and encourages the public to follow suit. The Volkswagen Foundation, the Thyssen Foundation, the Robert Bosch Foundation and the German Foundation for the Environment are only a few in a multitude of such foundations.

The foundations fulfil an important function in the science scene which goes far beyond their quantitative contribution to the German science budget. Among other things, they take up themes that are neglected or inadequately addressed by other providers of funds. Thus they often assume a pioneering role and contribute towards a balanced situation and equal opportunities in science and technology.

present, 15 % of the gross domestic expenditure on research and development are accounted for by all government and private research institutions together (1991: 14 %).

Among the non-university research institutions the national research centres, with a share of 36 % in this sector's R&D expenditure, play a dominant role and lead the field ahead of all government institutions performing research functions (17 %). The MPG which mainly focuses on basic research accounts for 14 %, the Blue List institutions for 12 %, and the FhG which is primarily active in applied research has a share of 11 % in R&D expenditure.

The third and largest sector of the research scene is the business enterprise sector with the research facilities of businesses and institutions for cooperative industrial research and development. At present, they account for about 66 % of domestic R&D expenditure (1991: 69 %).

The steel and mechanical engineering and vehicle construction industries have always participated most strongly in research and development (43 %), followed by electrical engineering, precision mechanics and finished metal goods industries (27 %), with the third position being held by the chemical industry (19 %). While R&D expenditure by the electrical engineering industry remained almost unchanged in recent years, the other industries in this bracket registered a slight increase in 1995 (3 %) compared with 1994 (2 %).

R&D-financing sectors

The strongest R&D-financing sector is the business enterprise sector. In 1994 it financed about 61 % of research and development performed in Germany; its self-financing ratio, related to R&D performed in the industrial sector, was nearly 89 %. The Federal and Länder governments rank second by financing approximately 37 %. Private institutions and the "abroad" sector contribute only about 2 % to financing research and development in Germany.

Since the late 1980s the business enterprise sector's share has been declining (1989: 63 %), while the contribution to financing national research and development by government and especially that by the "abroad" sector have grown. But in international comparison in terms of industry's contribution to financing, Germany still has a leading position among the G7 states behind Japan (68 %) and ahead of the USA (59 %). In Sweden and in Switzerland the business enterprise sector makes a similarly high contribution to R&D financing (62 % and 67 %, respectively).

Furthermore, expenditure on research and development performed abroad is gaining in importance. Since 1981 the share of funds channelled abroad in total business enterprise expenditure on R&D has more than doubled (2 %)[4].

In 1995 the R&D expenditure financed jointly by the Federal and Länder governments totalled about DM 32 billion, of which DM 1.8 billion were paid to the DFG and DM 2 billion went abroad, mainly for membersphip fees to international scientific organisations and institutions. In international comparison the Federal Republic of Germany thus holds a leading position in the field of civil research and development as 0.88 % of GDP are devoted to this purpose.

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[4]) This indicator, however, provides only limited information on globalisation (cf. Part II, Section 9.3).

German Research Foundation (DFG)

The German Research Foundation is the largest organisation hat funds research in Germany. As a self-government organisation of German science the DFG – by virtue of its statutes – serves all fields of science by funding research projects and supporting cooperation among researchers. Special attention is given to promoting and training young scientists. The Foundation independently elects the scientific members of its bodies.

In keeping with the principle of self-control of science its promotion policy is based on

- investigator-initiated research projects that are defined and will be performed independently by the scientist(s) concerned;
- peer review of the applications for funds by qualified, recognised scientists who do this work in an honorary capacity and apply the standards of scientific quality;
- competition for limited funds.

The DFG stimulates research by funding individual projects, while at the same time it helps build the structures of the research system by financing cooperative projects such as special research programmes and priority programmes. Special DFG schemes which focus on supporting and promoting young scientists are also expected to provide innovative scientific ideas. An important element in structuring and supporting the research system in Germany's new Länder is the funding programme for innovation-oriented academic research groups which is financed with special federal funds and for which the DFG is responsible.

Since they have very far-reaching effects the DFG assessment and funding procedures are of great importance for the quality of research in Germany. The DFG is thus a central player in the German research scene.

Figure I/7

Non-university research institutions and projects jointly funded by the Federal and Länder governments

		1996 budget* DM billion
Max Planck Society (MPG)	The MPG is the most important organisation for *basic research* performed outside the higher education sector. At present, it comprises more than 60 institutes and other facilities. The MPG is funded by the Federal and Länder governments on a 50 : 50 basis.	1.5
Fraunhofer Society (FhG)	The FhG is an organisation funding *applied research and development* with nearly 50 research institutes. Its objective is to encourage the use of new technologies in the business enterprise sector, thus strengthening Germany's international competitiveness. The FhG is funded by the Federal and Länder governments on a 90 : 10 basis (investment 50 : 50).	0.5
National research centres	The 16 national research centres (Helmholtz centres) united in the Hermann von Helmholtz Association of German Research Centres perform *scientific and technical* as well as *biological and medical R&D* requiring interdisciplinary cooperation and the concentrated use of human, financial and equipment resources. They cooperate closely with the higher education sector, non-university research institutions and business enterprises in Germany and abroad. National research centres are funded by the Federal Government and the respective host land on a 90 : 10 basis.	3.0
Blue List institutions	The institutions included in the Blue List are *independent research institutions* and *institutions with a service function* for research which is of supraregional importance and in the interest of national science policy. Currently there are 83 of these institutions. The Federal and Länder governments fund Blue List institutions mostly on a 50 : 50 basis.	1.3
Projects of the Academies of Sciences	This scheme which is coordinated by the Conference of the Academies of Sciences finances almost exclusively research projects in the field of humanities whose scope and duration exceed the lifetime of a single researcher and hence cannot be handled at higher education institutions. The scheme currently comprises about 150 projects. The expenditure eligible for grants is financed by the Federal and Länder governments on a 50 : 50 basis.	0.07

*Basic funding of institutions, projects of the Academies of Sciences, including funds from the Special University Programme II (HSP II) and from the University Renewal Programme (HEP), if applicable.

Source: BMBF

BMBF, BuFo '96

(The figures for other G7 countries are the USA 0.46 %, Japan 0.47 %, France 0.84 %)[5].

Present developments in the research system

The declining dynamism of industrial R&D expenditure, German unification and the reconstruction of East German research have changed the structure of the German research system over the last few years. As a result the share of the business enterprise sector dropped, while that of Federal and Länder governments rose as non-university research institutions and especially higher education institutions were built and expanded. It is only since 1995 that a slight increase in business enterprise expenditure on R&D has been observed (+1.8 %) which, however, has not yet resulted in any structural changes.

[5]) If defence research is included in this consideration, Germany – in terms of share of GDP devoted to R&D – comes third behind France and the USA (cf. Figure I/8).

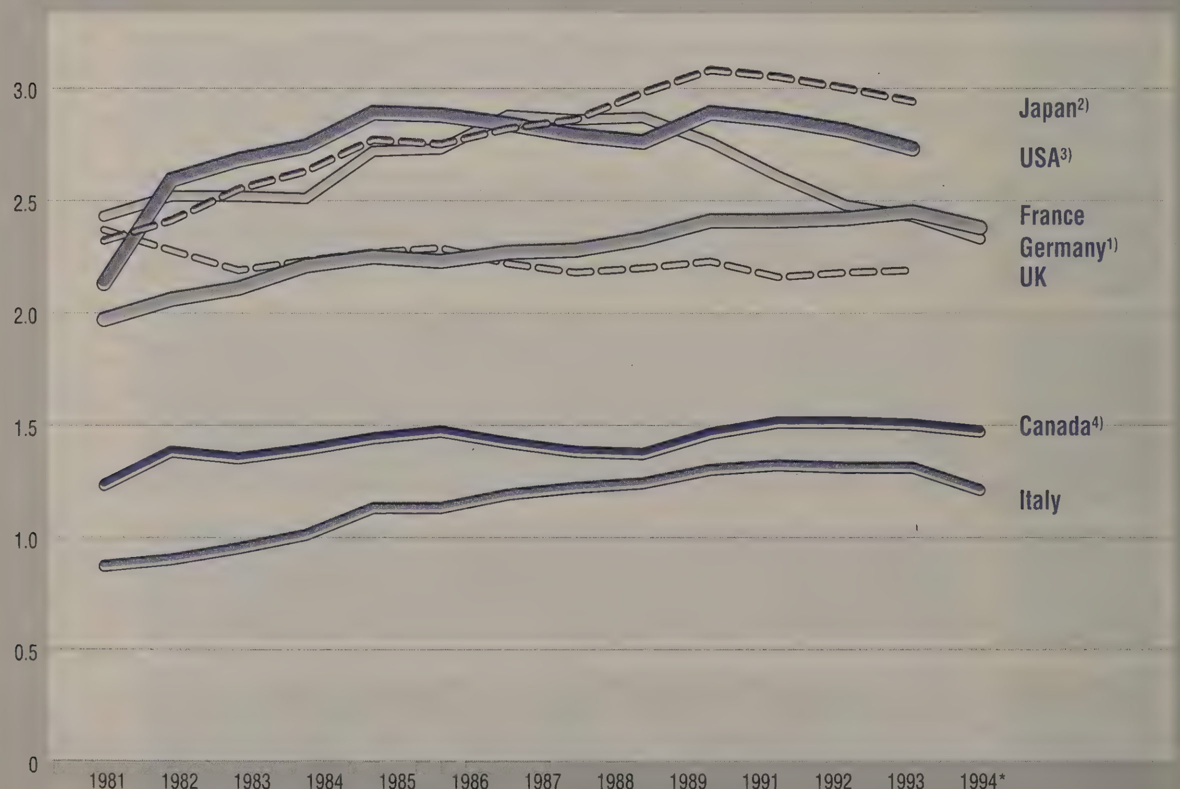
In spite of only minor nominal increases in the gross domestic product (GDP) in recent years the share of GDP devoted to gross domestic expenditure on research and development as a whole has decreased (since 1989) and amounted to 2.33 % in 1994. In an international comparison of the G7 countries Germany ranks fourth behind Japan (2.94 %), the USA (2.54 %) and France (2.38 %) (cf. Figure I/8). Among the OECD member states Sweden (3.26 %) and Switzerland (2.68 %) also have higher shares than Germany. A comparison of research systems shows that in Japan, the USA and Germany structures are more or less similar, with research institutions financed neither bei government nor by business enterprise playing a greater role in Japan and the USA than in Germany.

In Germany, a total of just under 500,000 people are working in research and development, among them about 240,000 researchers (47 %). With a share of basic research of approximately 20 % in total R&D expenditure Germany is holding a leading position on the international scale (France 21 %, USA 16 %, Japan 12 %).

Figure I/8

Gross domestic expenditure on research and development (GERD) in selected OECD countries, 1981-1994

in % of gross domestic product



* Provisional OECD data, based partly on national estimates, partly on OECD estimates.
1) 1987 break in series; 1986 and 1988 estimates, 1992 – 1994 revised estimates.
Up to and including 1990 former West Germany, from 1991 onwards Germany as a whole.
2) R&D expenditure overestimated or based on overestimated data.
3) Excludes most or all capital expenditure; 1991 break in series.
4) 1993 provisional.

Source: OECD (1995/2) and BMBF calculations

BMBF, BuFo '96

Interactions in the research system

In view of the multitude and diversity of schemes and measures on the one hand and the scarcity of resources on the other, mutual information and consultation of the partners involved in promoting and funding research are becoming more and more important.

A body that plays in important role in joint research funding and coordination as well as in mutual consultation and exchange of information, pursuant to Article 91øb of the Basic Law, is the *Federal/Länder Commission for Educational Planning and Research Promotion (BLK).*

In the *Skeleton Agreement on Research Promotion* the Federal and Länder governments agreed to share information subject to the pertinent recommendations developed by the BLK; this applies in particular to information on the principles and procedures relating to research funding as well as plans for new or existing research institutions and projects.

In addition, the BLK aims to coordinate the research policy plans and decisions of the Federal and Länder governments. General research funding schemes also need to be coordinated with big science and departmental research plans.

There is agreement within the BLK that the system of joint research funding has proved a success.

In 1957 the Federal and Länder governments instituted the Science Council to provide advice on issues relating to science and research. Its task is to prepare recommendations concerning the thematic and structural development of higher education, science and research. At the request of the Federal and Länder governments it also comments on specific institutions, developments or plans. Important examples are recommendations for university construction and comments on the higher education situation as a whole, appraisals of jointly funded research institutions as well as comments and recommendations concerning specific disciplines. The fact that the members of the Science Council are high-ranking representatives of science and government who have to undergo specific appointment procedures ensures that this advisory body enjoys an excellent reputation.

An outstanding example of the smooth cooperation between the Federal and Länder governments in research funding is the joint effort made to restructure and develop the East German research system.

Based on Article 38 of the Treaty on German Unity and the comments of the Science Council on the research work of the former academies as well as its recommendations for restructuring, over 100 research institutions have been set up since early 1992 which are jointly funded by the Federal and Länder governments. There are also three independent federal institutions and numerous institutes as well as branches of West German federal institutions so that all in all more than 140 non-university institutions with over 15,000 jobs have been created.

Renewing university research is an integral part of the restructuring process going on in the higher education sector in the new Länder. To complement the existing instruments of science funding target-specific funds were earmarked under the University Renewal Programme which amount to a total of about DM 2.4 billion. The objective is not only to renew the higher education sector in terms of personnel and

Legal basis

Responsibilities in the area of research promotion are divided between the Federal Government and the Länder governments according to the federal structure laid down in the Basic Law. Pursuant to Article 30 of the Basic Law, the exercise of governmental powers and the discharge of governmental functions is incumbent on the Länder unless otherwise provided for or permitted by the Basic Law. According to the allocation of powers laid down in the Basic Law, and within the framework of concurrent legislative powers, the Federal Government is responsible for legislation governing the promotion of scientific research (Article 74 No. 13 of the Basic Law). It has not, however, made use of its power to enact a general research promotion law. The *Framework Act for Higher Education* which also contains provisions relating to research (e.g. contract research) is based on the Federal Government's right to enact framework provisions on the general principles of higher education (Article 75 No. 1a of the Basic Law).

Pursuant to Article 91a of the Basic Law the Federal and Länder governments cooperate in the building and extension of institutions of higher education including university hospitals; in performing this joint task the Federal Government bears half the cost. The procedure to be complied with is laid down in the *University Construction Act*. It also provides for the co-financing of large-scale equipment for universities. Based on agreements concluded in 1989 and 1990 the Federal and Länder governments adopted joint Special University Programmes (HSP I and II) to continue the policy of keeping higher education institutions and research open and ensure their efficiency. Another agreement concluded in 1991 covers the University Renewal Programme for higher education institutions and research in the new Länder.

Pursuant to Article 91b of the Basic Law the Federal and Länder governments may, pursuant to agreements, cooperate in the promotion of research institutions and scientific research projects of supraregional importance. The Skeleton Agreement on Research Promotion of 28 November 1975, last amended on 8 November 1995, defines the group of eligible research institutions and projects as well as the coordination procedure to be applied.

Council for Research, Technology and Innovation to the Federal Chancellor

Established:	22 March 1995
Office of the Council:	at the Federal Ministry of Education, Science, Research and Technology
Members:	17 permanent high-ranking representatives of science, industry, trade unions and politics (for the Federal Government: BMBF and BMWi; representatives of the Länder: Bavarian Minister for Education, Culture, Science and the Arts) plus experts on specific issues to be addressed by the Council
Mandate:	– To draft a comprehensive situation report on potential applications, opportunities, obstacles and need for action in important areas of innovation – to initiate a broad-based debate on the future, to improve the acceptance of new technologies – to prepare recommendations for specific action to be taken by the players concerned on their own responsibility.

content but also to strengthen basic research and ensure an adequate infrastructure).

The higher education sector in the new Länder currently comprises about 50 universities, higher education institutions and Fachhochschulen at many different locations (cf. Part II, Section 7).

Coordination of research

While the coordination of research funded jointly by the Federal and Länder governments pursuant to Article 91øb of the Basic Law can be derived from the pertinent legal instruments, the Federal Government has created a specific concept for coordination at the federal level which is based on the principle of consensus. The most important elements are transparency and shared information, early coordination (before the funds are granted) of research projects exceeding a specific funding limit and mutual consultation in an inter-departmental committee (Inter-departmental Committee on Science and Research).

In addition, the instruments created at the level of Federal and Länder governments allow for mutual informal and continuous information on planned research programmes and measures to be taken to create new research institutions or a specific infrastructure. At the technical level the various pertinent bodies offer the opportunity for a regular exchange of information and experience.

Since it is primarily the Länder governments that are responsible for culture as well as research and teaching in the higher education sector, the *Standing Conference of the Länder Ministers of Education and the German University Rectors' Conference* are important bodies for coordination and cooperation.

With respect to sharing information, cooperation between science, industry and politics is becoming more and more important. This cooperation is ensured through bodies with joint membership such as supervisory boards, boards of trustees, expert advisory councils to research institutions and the like as well as regular meetings and forums.

Council for Research, Technology and Innovation to the Federal Chancellor

The Council for Research, Technology and Innovation instituted by the Federal Chancellor in early 1995 is a new important instrument of cooperation and consultation.

The first theme addressed by the Council was the "Information society – opportunities, innovations and challenges", a subject on which it drafted 41 recommendations. These recommendations were submitted to the Federal Government and taken up in the government's report "Info 2000 – Germany's transition towards the information society". Their implementation is part of the German information society initiative with which the government pro-actively moves into the multimedia age.

The next subject to be addressed by the Council will be "Biosciences".

Future challenges:
Task profile – lean research – networking – internationality

Owing to its multiformity German research can rely on a viable broad-based foundation which – from the government's perspective – needs to be strengthened and developed further in a dynamic fashion so as to enable it to meet the challenges ahead of us. In close consultation with the Länder governments, the science organisations and research institutions the Federal Government therefore strives to achieve the following objectives:

– Task profile

  New tasks cannot simply be tackled and solved by adding new institutes or research institutions, they rather call for a review of existing facilities and a definition of new priorities. Top-level scientific per-

formance and an excellent reputation are the criteria which in this process will be applied to all research institutions. The appraisal and evaluation by the Science Council of disciplines and research institutions such as those included in the Blue List is in keeping with the Federal Government's aim to raise the profile of the German research system. German research needs a consistent and lively performance and task profile to hold its own in international competition. At the same time the forces of competition and self-government within the science system need to be strengthened. Appropriate incentives to do so are provided by a more flexible grants system and the competition-driven allocation. of funds

– Lean research

Bureaucracy and red tape need to be cut back to allow for dynamic development. Research in particular calls for flexible structures and more latitude. This is why the government's initiatives to debureaucratise public administration and introduce more flexibility into the system are pushed vigorously also with regard to research institutions. Appropriate measures related to federal budget law are to help act more efficiently and with greater cost awareness and create new latitude in order to intensify cooperation between science and industry.

– Networking

To overcome obstacles between the generation and application of knowledge is one of the major tasks to be accomplished. Generating knowledge in the context of its later application does not detract from the importance of basic research; on the contrary, it creates a fruitful field of tension and stimulation. In some areas, e.g. in biological research using genetic engineering methods, basic research and the application of its results are only a few steps apart nowadays; even in the medical field, for example, application is still science at the beginning, because working and thinking patterns overlap. Traditional notions of "transfer" as a linear process leading from basic research to application-oriented research to innovation seem to be less and less convincing. Innovation is a process with many feedback loops into research. This is why the model for the future is cooperation between partners in joint projects and not passing the baton from stage to stage. Together with science organisations and research institutions the Federal Government will improve the conditions for this new process. Openness and networking between research and industry, including small and medium-sized enterprises, based on jointly defining research themes and pilot projects may play a key role in this process. This will have to be complemented by structural changes in research institutions. The transfer areas of the DFG and appropriate activities by the MPG (Garching Innovation) point in the right direction. Pilot innovation centres set up by the FhG are supported by the Federal Government. Similar initiatives are required in the national research centres and in the higher education sector. Structural openness and the ability to cooperate are indispensable prerequisites. In this process it is essential to network existing institutions rather than create new ones.

– Internationality

The international competitiveness of the German research system plays a key role for Germany's future. Global players will source internationally where they can find the best quality and lowest price. Research institutions have to be able to make offers in their respective areas at internationally competitive prices. This means that costs in the institutions themselves need to be managed in a highly flexible manner. It is not only important to develop one's own strengths, but also to establish fruitful partnerships. This is why the Federal Government aims to integrate the German research system into the European and international network of cooperations. The exchange of scientists and extended visits abroad are important elements of this effort. Research institutions need to grow together beyond national borders.

3.2 From research to innovation

Global competition for markets and customers confronts Germany with new challenges. Important competitors in the triad are more advanced in new technologies (microelectronics, biotechnology, computer science) and translate their results faster into new products to be launched onto the market. Furthermore, former NICs have developed into industrialised societies capable of innovation and marketing high-performance products at low prices. The dynamism of their development continues to grow.

But in spite of major successful rationalisation efforts German industry cannot win in international competition through favourable pricing alone. In many cases rationalisation is associated with shedding jobs so that new approaches are necessary. The future of Germany as an industrial location crucially depends on whether it will be possible to change from a defensive attitude to a pro-active one by using new technologies and turning them into marketable products. New jobs are created when innovative products and services help open up new markets and when innovative processes produce a competitive edge which compensates for locational disadvantages.

One characteristic of the new competition are the relatively short innovation cycles. This is why the speed with which competitors manage to place their products in the market is a decisive factor. Often a six-month delay in commercialisation can decide on the profit or loss of a company.

Analyses of the successes of international competitors and studies of the best methods to achieve innovation suggest that it is essential to bring science and industry together at the earliest possible stage. Innovations are not generated in a linear sequence of research and development, but rather in recurrent, sometimes parallel processes. Dynamic interactions are becoming a crucial factor.

The integrated research policy approach is designed to help improve a general setting conducive to innovation. In this process the development and support of cooperative networks will play a key role. They are part of the "Innovation '96" campaign which the BMBF has initiated to improve conditions which stimulate innovation.

Pilot projects as an element of research, technology and innovation promotion and funding

To take better advantage of the excellent research potential existing in Germany it is necessary for researchers and users to engage in early consultation on priority themes and issues. To this end, pilot projects will be introduced as instruments of a research funding policy.

These pilot projects are designed

- to promote the development of fundamental innovations,
- to ensure that the best solutions compete for implementing substantial innovations,
- to safeguard and strengthen Germany's position as a production location,
- to develop innovative networks involving both science and industry,
- to develop innovations in interdisciplinary and cross-sectoral projects,
- to use distributed know-how in a cooperative manner,
- to ensure fast and wide-spread dissemination of knowledge.

The function of pilot projects is to combine exacting tasks with specific application perspectives and bring together different disciplines and applications. The projects are to be proposed and developed in a bottom-up approach by partners willing to cooperate. The cross-fertilisation of market needs and technological capabilities is to lead to a competition of the best ideas for future-oriented innovation projects.

Integration into the innovation process of research institutions as partners and providers of technology services

In view of the growing importance of new technologies for the competitiveness of industry research policy is aiming to establish a closer cooperation between research institutions and businesses.

To achieve this end the Federal Government and the research institutions have joined forces. In October 1995 the Association of National Research Centres described its own perception of its function concerning the question of doing research for or with industry by making two policy statements which highlight the orientation of research towards innovation:

- "An essential prerequisite for the successful cooperation between research centres and industry is joint strategic planning where industry is already involved at the early stage of project definition."
- "An essential objective of industry-related activities of research centres is to protect existing jobs and create new ones that generate high value added in high-tech areas. Pilot themes and pilot projects with a long-term perspective are regarded as providing adequate thrust for agreeing on joint programmes with a clear definition of roles."

Both statements describe the road towards the often-suggested process of strategic coordination between research and industry which also needs to take account of the interests of small and medium-sized enterprises.

The Federal Government expects the national research centres to continue to intensify contacts between science and industry at all levels. It will actively support this process by increasing the flexibility of government research institutions through introducing private-sector forms of organisation as well as incentive structures. This will also include the accelerated introduction of improved conditions for cooperation with industry as well as further schemes designed to make financial and personnel management more flexible.

One step on the road towards closer cooperation between research institutions and industry could be that the institutions take on service functions. This proposal is gaining importance in particular with regard to future cooperation with SMEs. Often strong competitive pressure forces these mostly technology-based companies to innovate products or processes which – without support – they can only do with difficulty or not at all.

To strengthen these companies' competitiveness research institutions should be enabled to offer them access to laboratories and pilot facilities as well as direct assistance by scientists experienced in the technology areas concerned. The statutes of the research institutions are currently being reviewed with a view to making cooperation with SMEs in research and development projects easier. Any changes that might prove to be necessary will then be implemented without delay. It has to be ensured, however, that this will not lead to any distortions of competition at the cost of private service providers.

Initiative for setting up and supporting new technology-based firms

Small and medium-sized enterprises are an essential pillar of social market economy. The market economy system in particular thrives on personalities who can identify opportunities, take on risks and responsibility and use latitude to act. Getting access to the market by setting up new firms is a dynamic element of structural change and the resulting adaptation to changing market conditions. Modern policy for mid-sized companies aims to improve the competitiveness of German industry as a whole by strengthening the performance and innovative capabilities of SMEs. This is why the Federal Government regards a consis-

tent strategy of strengthening the market forces and opening up and keeping open the markets as a central part of its policy for middle-sized companies. Accordingly, obstacles hindering the development of SMEs need to be removed. The underlying principle is that special attention has to be given to the question as to whether and how economic policy action affects the development opportunities of SMEs. The Federal Government and management and labour have therefore started a campaign to promote entrepreneurship.

Small and medium-sized technology-based firms are central players in technological competition. Often it is these companies which translate the ideas of science into new products and get them to market quickly. This dynamism creates employment. Nearly two-thirds of the 2.3 million jobs created in West Germany between 1982 and 1994 were provided by new companies.

In German industry as a whole there is only a minor number of small technology-based companies working in R&D-intensive sectors of industry. Even the fact that a disproportionately high number of new firms were founded in recent years could not make good this deficit.

This is why Germany needs more new technology-based firms (NTBFs). But assisting these companies differs from providing grants to set up a new business. Unlike new craft enterprises, restaurants or retail businesses, young technology companies have to develop products and processes during the first two or three years of their existence; they also have to test prototypes in pilot applications and prepare production and commercialisation, i.e. they need to invest heavily which involves a considerable risk, whereas their equity position is usually relatively weak.

Other reasons behind special government support for small technology-based firms in Germany are difficult access to capital and information, comparatively higher expenditure on research and development, commercialisation risks that are difficult to assess, technical entrepreneurial risks as well as special requirements to be met by management.

This is why the Federal Government has given special priority to supporting technology-based firms. It will develop a new SME policy concept focusing on access for SMEs to venture capital and scientific results generated by universities and research institutions. Pioneering entrepreneurs will be actively assisted and cooperation of small and mid-sized companies with scientists will be promoted.

Appropriation of capital for innovation

The central issue for NTBFs is access to risk capital. When people have the necessary ideas, skills and competence and are prepared to take an entrepreneurial risk they must not be thwarted by a lack of access to capital in this country.

For this reason the Federal Government supports schemes designed to improve the capital resources of SMEs:

- The nation-wide scheme "Direct-investment capital for small technology-based enterprises" offers incentives to equity investment companies and other investors to buy into young and small companies. By broadening the equity capital base these firms are to be enabled to implement their innovations on a secure financial basis and to establish themselves successfully in the market. The equity capital may also be used for investing in commercialisation. Depending on the scheme version a maximum of DM 4 million or DM 6 million will be available. Experience has shown that commercialisation usually begins in the second or third year.

- Under the ERP innovation programme low-interest loans are granted to small and mid-sized companies which are engaged in research and development. The objective of this programme is to increase the technological competitiveness of SMEs so as to enable them to translate their ideas more quickly into sophisticated marketable products and put these on the market. The annual credit volume is at least DM 1 billion. During the R&D phase the ceiling for a loan is DM 10 million and during the commercialisation phase DM 2 million or DM 5 million, depending on whether the company in question is based in the old or the new Länder. At present, the interest rate for firms in the old Länder is 5.5 % and 5.0 % for those based in the new Länder. Extended support may be offered to companies in the new Länder during the launching phase.

- To improve the basis for making decisions on granting loans to, and negotiating capital for, technology-based companies specialised technological know-how is made available by government-funded research institutions, investment companies and banks.

- The Federal Government regards the participation of German players in the EASDAQ project (European Association of Securities Dealers Automated Quotation System) as a possibility of improving access to risk capital.

Under its "Action Programme for Investment and Jobs" the Federal Government will help SMEs and new companies to gain access to risk capital. Measures envisaged include easing the strain on the equity capital base of companies, especially by introducing a corporate tax reform as well as reforms of inheritance, gift and capital taxes, the swift implementation of the EC Council Directive on Investment Services in the Security Field, creating the legal basis for investment companies as public limited companies, modernising the legal regulations governing liability extending to statements made in issuing prospectus, reforming the support of equity investment companies and increasing the attraction of companies participating in non-listed enterprises as well as of the venture capital process. Furthermore, the Kreditanstalt für Wiederaufbau (Reconstruction Loan Corporation) has initiated a programme designed to mobilise additional venture capital for innovative mid-size companies.

Support of SMEs in the new Länder

With great determination and substantial funds the Federal Government – through its funding programmes – has helped East German industrial research on its difficult way. The support provided by the research ministry which began as early as September 1990 focused first of all on funding research contracts. Thus SMEs could very quickly acquire the latest know-how in order to strengthen their innovative capacity. Furthermore, funds were granted for recruiting additional R&D personnel.

Another important priority is the support of new technology-based firms and the development of a suitable environment for these companies to help build up innovative mid-size businesses. Scientific evaluation of these special programmes for East Germany has shown that they have been extraordinarily effective.

In addition to these special programmes support under nation-wide specialised programmes and the SME scheme "Research cooperation" had a tangible effect on the development of innovative mid-size industry structures in Germany's new Länder.

Since 1990 the Federal Ministry of Economics (BMWi) has concentrated on supporting R&D potentials and developing new products and processes in small and medium-sized businesses in the manufacturing sector. It also assisted R&D and service institutions which had been newly founded or hived off into independent operations and provided funds for building a technology infrastructure.

The scheme "Grants towards R&D payroll cost in the East" encourages small and medium-sized enterprises in the manufacturing sector to stabilise or increase their R&D potential and to improve their competitiveness through innovation as well as to gain new market shares.

The promotion programme "Pre-competitive industrial research and structural change in industry" aims to assist external industrial research facilities and R&D service providers through innovative R&D projects. It serves to support the development of powerful innovation potentials which are of special importance for mid-size business enterprises.

The BMWi is withdrawing from schemes promoting the development of new products and processes („Innovation promotion scheme") in SMEs as these initiatives will be continued by the Länder governments. From 1992 to 1995 these programmes helped develop about 1,000 projects in approximately 800 small and medium-sized enterprises. Since 1991 the Federal Government has allocated a total of DM 3.2 billion to industrial research in the new Länder. This means that 40 % of the funds spent on R&D by the business enterprise sector were appropriated under federal promotion schemes. More than 80 % of all R&D-performing businesses in the new Länder could benefit from such funding so that considerable progress could be achieved in the development and restructuring of powerful innovation potentials in the business enterprise sector.

In view of the substantial advancement of corporate research capacities the Federal Government is currently working intensively on restructuring the special funding schemes for industrial research in the new Länder to take account of present conditions. The support of corporate research is to gain more weight, bearing in mind that in the new Länder a substantial part of industrial research is performed outside the companies in external research facilities. At the same time incentives are needed to induce businesses to embark on especially innovative projects which aim to open up new markets by taking advantage of a technological lead. Furthermore, the vigorous support of newly founded companies is considered an important tool for the further development of innovative SMEs.

Supporting units hived off from research institutions

New technology-based firms set up by staff of research institutions (units hived off into independent operations) are an important vehicle for turning R&D results into industrial applications or for privatising scientific and technical services that cannot be provided by the institution itself even though they are based on its know-how. Such hived-off units complement the set of instruments of technology transfer via brains, they give research institutions sufficient latitude to take on new research tasks and create additional jobs in an area of high value added.

The working programmes of the national research centres are still not sufficiently geared to the needs of SMEs, and new technology-based firms have to take a relatively high risk. These two factors, together with administrative obstacles, are the reason why the potential for hiving off units from institutions which does exist in national research centres and the Fraunhofer Society as well as in other scientific and technical research institutions has not yet been fully realised. In the more application-oriented areas of national research centres about 10 operations are currently hived off every year. Approximately 250 companies with about 1,000 employees were set up by former staff of the Fraunhofer Society.

The Federal Government intends to encourage more SME-oriented work in the research institutions and create a general setting that enables staff to perceive their know-how as an opportunity and set up companies of their own.

A coordinated set of measures will help research institutions encourage and support people intending to set up new businesses. Unless it is specifically designed for employees of the research institutions, this funding scheme will also apply to those potential founders who are not staff. It includes the following specific measures:

- To arrange counselling and training sessions based on the services available from agencies already active in this field, especially chambers of industry and commerce;

- to consider whether a research and development result obtained in a research institutions may provide the technical and economic basis for a new business to be hived off from the institution;
- to make rooms, equipment or licences temporarily available at market conditions;
- to second staff against cost reimbursement;
- to grant permission for a side-line occupation with or without the permission to work part-time;
- to grant limited leave and/or agree to re-employ the person(s) concerned.

The success of this scheme will primarily depend on whether or not the research institutions intensify their cooperation with SMEs.

Legal framework

In its research policy the Federal Government clearly emphasises the improvement of the legal framework for research and innovation. It intends to work already in the ongoing legislative process towards ensuring that the concerns of research and innovation are not affected at all or only to the extent required to protect higher legal interests. In addition the BMBF is studying the possibilities of eliminating non-legal obstacles to science, research and innovation.

With regard to existing legal norms the report submitted by the independent expert committee on planning and licensing procedures (so-called conciliation committee) which the Federal Government had commissioned included a number of proposals designed to improve the legal framework (e.g. to introduce research clauses in specific laws relevant for research, to replace licensing procedures with notification procedures or at least ease administrative rules for research institutions). The Federal Government has already responded to the committee's proposals and developed bills designed to simplify and speed up planning and licensing procedures. In the course of amending the provisions relating to the protection of environmental quality the Federal Government has presented an amendment to the ordinance on facilities subject to licensing which makes it quite clear that research and development facilities, especially laboratory facilities, are not subject to licensing. In the future, the manufacture of products and testing their properties by third parties prior to commercialisation will not be subject to licensing either if the new products are to be further studied and developed. This ordinance is subject to the approval of the Bundesrat, Parliament's upper house.

In this project the BMBF is supported by the so-called clearing-house for innovation and legal issues. This is an informal body composed of representatives of the Helmholtz Association of German Research Centres, the Federation of German Industries, the German Research Foundation and the Association of German Chambers of Industry and Commerce. It collects complaints and comments addressed to the various groups of researchers it represents. It also provides a forum to discuss bills drafted by the Federal Government, the removal of obstacles in existing law and rules relating to future technologies.

Patent promotion

Patents have a dual economic function. They specify and document the research result in order to protect the rights of the inventor (protective function). They also further the translation of research results into marketable products (transfer function).

To safeguard R&D results for commercialisation in Germany research institutions as well as small and medium-sized enterprises need to pursue a more active patent policy. Already during their university training students in appropriate disciplines should be familiarised with the patent system.

The BMBF is preparing to improve the general conditions for inventors and to introduce a patent initiative in research institutions as well as a campaign to support SMEs when they first apply for proprietary rights. The INSTI project (stimulating innovation in German industry by providing scientific and technical information) which has just been initiated will ensure through a nation-wide network that inventors will be given better access than before to existing information. The Patent Agency for German Research of the Fraunhofer Society in Munich helps free-lance inventors, and not only research staff, to obtain a patent and utilise it for granting licences. In 1995 the possibilities of getting a grant to cover the cost of obtaining a patent were improved. It is now also possible to obtain grants for building operational specimens and prototypes to improve the chances of marketing an idea.

Improved general conditions are expected to remove existing obstacles and give inventors easier access to effective, low-cost proprietary rights. At the international and European levels the Federal Government advocates the re-introduction of a period of grace for inventions. The fees for the grant of a patent by the European Patent Office can only be reduced in agreement with the member states of the European Patent Organisation; reduced fees, however, are crucial to providing easier access to patent protection via the European channel. Taking the initiative, the BMBF is currently amending the rules which relate to proprietary rights and apply to BMBF grants.

The patent initiative started in research institutions is focusing on information campaigns concerning the significance and value of proprietary rights. However, publications and patents are by no means mutually exclusive, provided the correct order is observed, i.e. patent first, publication second.

The intention to support small and medium-sized enterprises when they file a patent application for the first time is based on the general recognition that SMEs frequently come up with patentable inventions, but do not apply for a patent not only because of economic considerations, but also due to ignorance of, or reservations about, the procedure involved. These companies need to be introduced to the patent system. It is especially important that they overcome

any potential fear of the unknown. Only personal experience with the patent system will lead to an increasing number of applications. This is why it is intended to run information campaigns and provide grants towards the first patent application costs of small firms.

In a pilot project extending over several years the BMWi financed the development of patent inspection offices into efficient patent information centres with a view to improving the information, of SMEs in particular, on the current state of technological development. It is now planned to modernise the equipment of these centres. Under a special scheme the BMWi funded a project designed to evaluate unused former GDR patents and make the economically relevant inventions available for use, especially by SMEs.

Technology transfer

Against the backdrop of the rapidly growing pressure for innovation in combination with an increasing number of providers and ever shorter product life cycles the innovative use of new technological possibilities is becoming a crucial factor for competitiveness. Exploiting the technological knowledge base has proved to be very important as well. This is why the adequate organisation of the transfer of knowledge and technology from science and research to industrial application is becoming a key factor in maintaining our competitiveness.

In the past the Federal Government has taken this development into account and used various channels to support the implementation of technological information. Such channels include programmes intended to stimulate contract research as well as research cooperations which – by establishing close links between research and practical application – enable available technological know-how to be utilised. In the new Länder the Federal Government has supported the development of agencies funding technology transfer and innovation as well as sector-specific and technology-specific transfer centres. Responding to the specific needs of the East German economy, these transfer facilities provide innovation-oriented development services for industrial companies.

In the future government commitment to improving the transfer of technology will shift more towards direct transfer between universities/research institutions and businesses. Recent studies have confirmed that technology transfer works less through passing on technological know-how to future users, but rather by involving industry and science in relevant joint projects at a very early stage.

More than in the past technology transfer agencies will have to establish contacts between science and industry in the run-up to research and development work in order to enable the partners jointly to carry out projects.

The following considerations represent important elements of technology transfer:

- Scientists must be motivated to ensure that the transfer of their knowledge is successful. This can be encouraged by incentives such as bonuses and participation in license contracts.
- A special part of the institutional budgets should be allocated to contract research.
- Research institutions need to be encourage to develop projects to the transfer stage in cooperation with businesses, where possible.
- Transfer agencies need to acquire the qualifications necessary to assist scientists in contractual matters as well as in patent and licence issues, questions of marketing and invention and in establishing initial contacts.

Not only scientific achievements in the traditional sense, but also success in technology transfer – especially success in obtaining patent protection for R&D results which is fundamental for innovation – should be identified and form part of the appraisal of research institutions and the performance of individual scientists. The approach taken by the Science Council of giving equal weight to patent applications and scientific publications in evaluating a research institution is an important practical step in this direction.

3.3 Research – the workshop for the future

Research is the expression of fundamental open-mindedness and hence prerequisite to versatility and adaptability. Research opens up new possibilities for action and at the same time warns us against spurious certainties. Its experimental character eludes any ideologisation. Research is thus an important guarantor of the freedom of modern societies. The task of exploring the resources of human life and existence, studying the possibilities of safeguarding them, and investigating potential threats caused by human action and making people understand all this, is more and more becoming the most important responsibility of the sciences – and this responsibility also includes the impact of science-based action. Science and research are thus taking on the central functions of an "early detection system" and "seismograph" drawing attention to undesirable developments. They provide important decision-making aids for a responsible future-oriented policy.

Responsibility for the future makes research and its funding virtually an obligation. The analysis of developments, their causes and consequences creates the basis for new problem solutions and hence possible action aiming to prevent damage or improve human living conditions.

Research is an indispensable compass helping us to get our bearings. Nowadays the increasingly sophisticated scientific tools enable us to make more valid statements on complex processes. Comprehensive studies such as the report on 'Technologies at the beginning of the 21st century' which had been commissioned by the BMBF paint a quite varied picture of foreseeable technological development paths. Sophisticated procedures like patent and citation analyses as well as relevance tree analyses can help identi-

fy the changing structures in science and technology. "Research mapping" permits us to draw conclusions as to the convergence or diversification of research areas; research profiles can be developed and compared with each other.

Also the USA, France, the UK, Korea, Australia and the Netherlands have conducted new prospective studies.

They have shown that the joint process of "seeking the future" itself is a decisive criterion for the success of the attempt to predict future technologies.

The first "German Delphi Study on the Development of Science and Technology", performed in 1992/93 by the Fraunhofer Institute for Systems Technology and Innovation Research (FhG-ISI) in cooperation with the Japanese National Institute for Science and Technology Policy (NISTEP) has taken up this idea in a special way: In two rounds more than 1,000 experts from science and industry were questioned about the developments of the next 30 years. Coordinated by this study, the scientific community embarked upon a broad-based analysis of the present basic conditions for R&D and the ranking of 16 technological areas. As this process took place simultaneously in Japan and Germany, insight could be gained into the interaction between cultural background and society's dependence on technology, an important perspective in the age of global markets. The Delphi approach was developed further in cooperation with Japanese partners and adapted to German conditions (‚Mini-Delphi").

A second German Delphi study is already underway. It will attempt to use the experience gained and identify new innovation themes that are important for Germany.

Even though science permits us to predict possible future developments, the process of developing scientific knowledge itself teaches us that all forecasts have their limitations. The study of biological and social processes, for example, has shown that these are so complex and variable that forecasts always have to admit that things may also develop along completely different lines as well. Scientific knowledge hence contradicts historical determinism and thus reminds us of the fundamental diversity and freedom of human action. It is in this function as guarantors of freedom – which at the same time highlights the personal responsibility involved in using this freedom – that science and research display their power to influence intellectual and cultural developments.

3.4 Research needs education

The future of science and research greatly depends on the quality of education and the qualification of researchers. The training of young scientists at higher education institutions is of key importance. The Federal and Länder governments are called upon to support the higher education sector in accomplishing this task.

Further reforms in the higher education sector are indispensable as the situation at universities is still unsatisfactory:

- According to current standard values only about 970,00 study places are available for approximately 1.9 million students. While in Germany's old Länder the number of new students has increased by 75 % since the Länder premiers decided in 1977 to open the universities, the number of scientific staff has risen by only about 11 %. Average study periods are now seven years at universities and more than five years at Fachhochschulen.
- Educational attitudes and expectations have changed fundamentally, but the structures of study courses have not yet responded adequately. Today 24 % of new students at universities and 65 % at Fachhochschulen have already successfully completed a vocational training course. About 600,000 students are currently striving to obtain dual qualifications, i.e. formal vocational training and an academic degree.
- The international attraction of a German university education has worn off.
- The use of modern information and communications technologies for studying and education is underdeveloped.

This is why the Federal Government has charted the future course with its initiative to introduce structural reforms under the Federal Training Assistance Act. The aim is to increase the funds earmarked for the joint task (of the Federal and Länder governments) of university construction, to introduce new internationally oriented study courses, and to make wider use of information and communications technologies in higher education.

But further reforms are still necessary. On 1 March 1996 the Standing Conference of the Länder Ministers of Education adopted the report on the implementation of measures decided upon in the policy paper of May 1993. The report clearly indicated that a more expeditious and homogeneous implementation of the reform measures in the Länder was urgently required. This goes beyond the structural reform of academic studies and equally applies to the performance-based allocation of funds to universities and to creating more latitude for decision-making by higher education institutions themselves – ranging from the use of funds to student selection.

It is also apparent that for foreign students and young scientists Germany is losing its academic attraction. Under the 1992 – 1994 Human Capital and Mobility (HCM) Exchange Programme, for instance, only about 10 % of 1,755 successful candidates had applied for a stay in Germany, while 32 % had opted for the UK and 27 % for France. More and more young German scientists go abroad without a sufficient number of young foreign scientists coming to Germany. The Federal Government gives priority to counteracting this trend. The BMBF is taking the following measures to internationalise higher education and research institutions

- By introducing new study courses with an international focus the BMBF plans to increase the attraction of studying in Germany. The underlying idea is that about 50 % foreigners and 50 % Germans should enrol in these study courses, e.g. in economic and engineering sciences; the courses will strictly comply with the present standard periods of study and they will be held alternately in German and a foreign language.
- The Federal Government will do its best to ensure that existing regulations relating to the entry into, and residency in, Germany of foreign students and young scientists are fully applied nation-wide and a potential scope of discretion is used.
- German academic degrees need to become more compatible at the international level. German universities, for example, usually cannot offer to foreign students holding a bachelor degree a competitive postgraduate course ending with a qualification comparable to a master's degree. Bachelors are usually graded at so low a level that to get a German diploma they have to stay at university much longer than they would have to elsewhere to get a master's degree. In this context it also has to be considered whether the requirements for a doctorate or a professorship should be modelled more on international standards and profiles.
- Higher education is of paramount importance for Germany's performance and innovative capacity.

Promoting young scientists

The further development of our highly complex society depends on performance elites in many areas. To develop in the right direction young talents in the population need to be supported. Unlike other countries the Federal Republic of Germany began only in the early 1980s to develop target-specific funding programmes for academically able children. Today the schemes supported by the BMBF include a large number of nation-wide contests. The events organised every year during the summer holidays by the Academy for the Talented offer additional possibilities for promoting young talent. Organisations for funding the education of young people with special academic abilities, which are an indispensable part of the pluralistic system of funding education and science, look after especially talented students and young scientists.

In this context, the extension of the promotion scheme for young talents to include vocational training as well which the Federal Government had pushed pro-actively over the last few years was a major step forward. The BMBF is currently assisting 12,000 young skilled workers in its "Vocational Training Programme for the Highly Talented". This means that the numerical goal of this scheme which was introduced in 1991 has been reached. The number of young people assisted in this field equals that in the higher education sector. After the BMBF has successfully initiated this new funding area, it will now be taken over by a separate industry-related association for funding the education and training of highly talented young people.

An important step towards the specific preparation for occupations in research and science was the joint intention declared by the Federal and Länder governments in the early 1990s to make a clearer distinction in university studies between study courses providing specific occupational qualifications, on the one hand, and the training of young scientists for work in research and science, on the other. It was agreed then that in addition to the classical doctorate postgraduate studies should be developed further. The number of such study courses is to be increased to about 300 by the end of the century to give a growing number of young scientists the opportunity to prepare for a future career in science while giving special consideration to interdisciplinary matters. The doctoral scholarship system will continue to play an important role because a minimum of financial security is a necessary prerequisite for ensuring the subsistence of young scientists at a time of special challenges and stress. It should also be considered whether outstanding young scientists should be given the opportunity to embark on more independent research work.

In the next decade an extraordinarily high number of scientists in Germany will reach the retirement age. Extrapolations suggest that it will be 50 %, with the figure being even higher in specific subjects. This means that in this country the common international replacement rate of 4 % will be clearly exceeded. This trend is reinforced by the high replacement needs for scientific staff at higher education and research institutions in the new Länder in the wake of university renewal which began in 1990. In this phase of German science development the promotion of young scientists by universities is of paramount importance. Only universities combine within one single institution all that is indispensable for training young scientists:

- At the universities research extends over the entire range of scientific issues and disciplines so that it offers a perfect opportunity to establish interdisciplinary links between scientific areas.
- As institutions designed to safeguard, extend and transfer scientific findings universities combine research, teaching and the training of young scientists;
- Universities are constantly confronted with subsequent generations and their specific thirst for knowledge, often tackling unconventional issues and new working methods.
- In many areas, such as the humanities, universities are the most important, sometimes even the only institutions performing and funding research.

Within the scope of its responsibility and the limits of its powers the Federal Government will continue to support the universities in accomplishing these tasks. At the same time it calls upon the Länder governments not to weaken in their efforts to provide special assistance to young scientist also in times of great financial strain. In particular, the question has to be

answered how the increasing demand of young scientists for positions can be met satisfactorily.

Promoting and funding applied research and development at Fachhochschulen primarily serves to improve their ability to raise external funds. As a result it also contributes to promoting young scientists at Fachhochschulen. Participating in research projects provides better qualification possibilities for young people who are interested in long-term work in research and science. For years the BMBF has advocated the idea of giving specially talented Fachhochschule graduates the opportunity to study for a doctorate at a university without having to spend a long time acquiring a university diploma first. The new Länder have embodied this possibility for Fachhochschule graduates (in part on a cooperative basis) in the pertinent Länder laws. The Federal Government has observed with criticism that such possibilities are only hesitantly realised in the old Länder. In the interest of promoting young scientists more effectively it is necessary to open universities more to doctoral candidates from the Fachhochschulen.

By the same token, the question arises whether closer cooperation between universities and non-university research institutions, which is basically accepted, has already reached that level of intensity that seems to be desirable for providing optimal research and qualification opportunities for young scientists. Appointments to both universities and non-university research institutions – a procedure which by now is largely common practice – are an important prerequisite for ensuring that young scientists can make use of all resources available so that they can enjoy optimal support in their individual development.

3.5 Women in research

A future-oriented education and research policy would be incomplete without an increased utilisation of the education and innovation potential of women. While internationally, especially in the USA, Northern and Western Europe and also Japan, the way points to equal participation of women in all areas, it should also be possible in Germany to overcome engrained structures and restrictive ideas. Examples abroad show that the promotion of women in research and technology, especially in leading positions, is an indispensable part of personnel development in innovative, market-focused, competitive companies. It is also uncontroversial that the still low number of women holding C3 and C4 professorships (highest levels) in higher education institutions and leading positions in non-university research institutions highlights still existing career disadvantages for young female scientists. Female C4 professors account for only 4 %, although almost half of all students are female. At general school girls are already more interested in higher education than boys. In 1994 girls accounted for 51.3 % of all pupils at intermediate schools and 54.2 % at grammar schools. This is why for a long time it has been one of the declared objectives of the Federal Government to create adequate conditions for women in Germany to pursue a scientific career.

Women's studies are expected to provide new impetus for involving more women in science and research. Such studies may be described as a cross-disciplinary science based, among other things, on findings of social research, philosophy and linguistics. In the USA women's studies have for decades been a driving force of progress in a large number of disciplines. The platform for action adopted at the Fourth International Women's Conference in Beijing also includes the demand to expand women's studies at higher education and research institutions. The Federal Government intends to make women's studies one of the more visible elements of its R&D policy in the years to come.

But supporting women's studies alone does not yet make for equal participation of women in the innovation process.

This participation has to set in already with an increased involvement of women in the decision-making processes preceding the definition and selection of research themes. Cooperation of men and women on an equal basis in the field of science will generate visible value added for scientific research.

The Federal Government has taken a number of initiatives to attract more women to natural science and engineering disciplines:

- Under the Special University Programmes the Federal Government is working towards considerably increasing the number of women obtaining doctorates and professorships in all disciplines in order to create an adequate potential of female candidates for the time when a new generation will take over in higher education over the next ten years.
- The Federal Government advocates an increase in the number of women in scientific advisory and decision-making bodies. The appropriate legal basis is provided by a law governing the composition of such bodies.
- To ensure a general setting that promotes women in science and research it is necessary to create conditions that are favourable for families; this is why the Federal Government will work towards introducing child care allowances into the pertinent scholarship and qualification programmes.
- The BMBF intends to include exemplary projects relating to women's issues in specialised R&D programmes.
- The BMBF is working towards giving a high profile to exemplary achievements by women as well as towards carrying out schemes in the engineering sector which are specifically targeted at women. These include the initiative "New impetus for technology by women" which is designed to further the comprehensive support of, and positive perspective for, women in the engineering sector. The initiative is implemented by the BMBF in cooperation with the Federal Institute for Employment, Deutsche Telekom, the EU as well as the two sides of industry.
- It is intended to tap the potential of women to a greater extent through studies and pilot develop-

ments in the field of initial and continuing vocational training of women in technical occupations, also using multimedia.

- In telecooperation and telework research projects the BMBF funds those schemes in particular that open up full access to educational and occupational possibilities for women. In the future another priority will be the use of new technologies to improve the compatibility of work and family for men and women, including those holding highly qualified jobs.

4. Visions for a future-oriented research and technology policy

4.1 High technology for manufacturing and services – opportunities for more employment

Industry, services and employment

Secure jobs, stable incomes, social security, affordable services – in a high-wage country like Germany all this depends greatly on a strong and competitive manufacturing sector. There is no such thing as a service society without industry. But in global competition manufacturing and services are increasingly integrated. In addition to the aspect that new products need the latest and best technology there is another component: Complete systems solutions have to be offered, ranging from the identification of the problem to customer and product service. A case in point is selling machines including adequate maintenance and repair services. Machine building companies achieve market success by supplying a diagnostic computer for maintenance together with the machine and offering appropriate services to repair any breakdowns. In this way they provide all-in customer service regardless of time or place.

The importance of company-focused and product-oriented services in combination with production can hardly be overestimated. These services are becoming a decisive factor for the future orientation of manufacture, research and development and hence the competitiveness of the company concerned. The production costs of technology-based products today account for only about 25 % of product costs. An average 75 % is accounted for by the costs of associated services such as product development and design, technical services, qualification activities, raising of capital, waste management and recycling activities or management consulting. The age of mass production is drawing to a close, interaction with the customer – enhanced by modern information and communications technologies – is growing. With his precise expectations the customer is becoming an important "co-producer". Above all, the future lies with developing new services adapted to customer requirements and designed jointly with the customer, thus achieving differentiated service markets.

Managing in cycles, a model for an ecologically sound industrialised society conserving natural resources, also calls for an interaction of manufacturing and services. What is needed is an intelligent network of different production areas and services which leads to the development of competitive integrated systems approaches. The development of high-tech materials and new compounding and processing techniques is just as necessary as intelligent material flow management based on modern information and communications services.

Opportunities and challenges

Path-breaking research and development play a central role for providing a comprehensive range of products and services. They prepare the ground for product and service leadership.

Germany is facing the challenge of focusing even more on high technologies than it used to do in the past. It is only in this way that the highly qualified new jobs of the future can be created in those fields which surround the high-tech core areas. The relevance of these jobs for overall employment is not expressed in their immediate quantitative effect.

High technology and services

Example: Laser technology

Laser technology permits the gentle cleaning of high-quality surfaces such as the outer shell of aircraft. When the outer coat of paint of an aircraft has been damaged and become rough the drag becomes too high. While so far complicated chemical treatment has been necessary which resulted in problems with highly polluting waste, use of the latest laser technology brings decisive advantages. With the laser beam paint can be removed coat by coat. All that is left is a powder that can be easily disposed of. By means of a high-tech instrument a new service can thus be provided offering many advantages and market opportunities.

Example: Superconduction

The latest superconduction technology permits low-loss power transmission and hence strong magnetic fields. Based on this technology computer tomography could be developed which opens up considerable opportunities for new services in the health care sector. Computer tomography offers greatly improved opportunities to diagnose cardiovascular diseases, cancer and severe injuries. Computer tomography is an example of the use of high technology for medical diagnosis.

Service sector still expandable

It is a striking phenomenon that those countries which hold a dominant world market position in the high-tech sector such as the USA and Japan also generate more value added and create more jobs in the service sector. According to an analysis by the Ifo Institute as much as 58 % of the US labour force works in the private service sector; also in Japan the rate is much higher at 50 % than in Germany with 39 %. Based on high technologies services could help generate high value added and create new jobs in the private sector.

The majority of jobs will not be created in the high-tech sector itself. But jobs which persist in international high-technology competition create many new employment opportunities in their environment due to their high value added potential.

Strategies to enhance high technologies

The Federal Government is funding the research into and development of high technologies which offer a high innovation potential for manufacturing and services. Its main focus is on an integrated systems approach in the high-tech area:

- Guided by the idea of ecologically sound, competitive production the "Production 2000" framework concept combines approaches from various technology areas. Managing in intelligent cross-sectoral and environmentally acceptable cycles is to help optimise the production process and develop self-contained concepts for the world market. Those production processes will be most competitive in the medium term which close the material, energy and product cycles, i.e. take into account the entire life cycle of a product including its possible reuse. After all, the "Production 2000" funding concept is about the future of the manufacturing sector in Germany which employs about 11 million people (38 % of the total labour force). At the same time this concept will contribute to keeping and, if possible, expanding Germany's international top position in environmental technology.

- The "Laser 2000" funding priority aims to make use of the varied potential of laser technology for miniaturisation and productivity gains. Precision machining of materials using laser technology has virtually no limitations. The high energy density of the laser allows for environmentally sensitive processes. There are numerous potential applications in production as well as in the service sector (e.g. in health care) because laser technology ensures maximum quality and hence competitiveness. All in all, it is expected that by the year 2000 180,000 to 200,000 employees in Germany will be involved in the production and application of laser equipment (see Figure I/9).

- The "New materials" programme is focusing on application-related materials research for the dynamically developing markets for information, transport, energy, medical and manufacturing technologies. There is a ubiquitous demand for specific material properties such as special hardness or tearing resistance which require studies of interfaces and surfaces as well as of the interaction of different materials. Resource-conserving and environmentally sensitive properties of new materials are of particular importance. A technology which is still only at its beginning is nanotechnology which makes it possible to develop materials with particle sizes in the nanometer range. By combining extremely fine metal and ceramic powders components can be produced that withstand specific mechanical and thermal stress. The nanometer scale will become the future standard of precision in materials analysis (see Figure I/10).

- The "Microsystems" funding scheme is also designed to push high technology based on microsystems. It focuses on converting microsystems-based prototypes and laboratory-scale samples into standard and serial products, e.g. in measuring and control processes. There are numerous obvious applications, e.g. in the environmental and health care sectors.

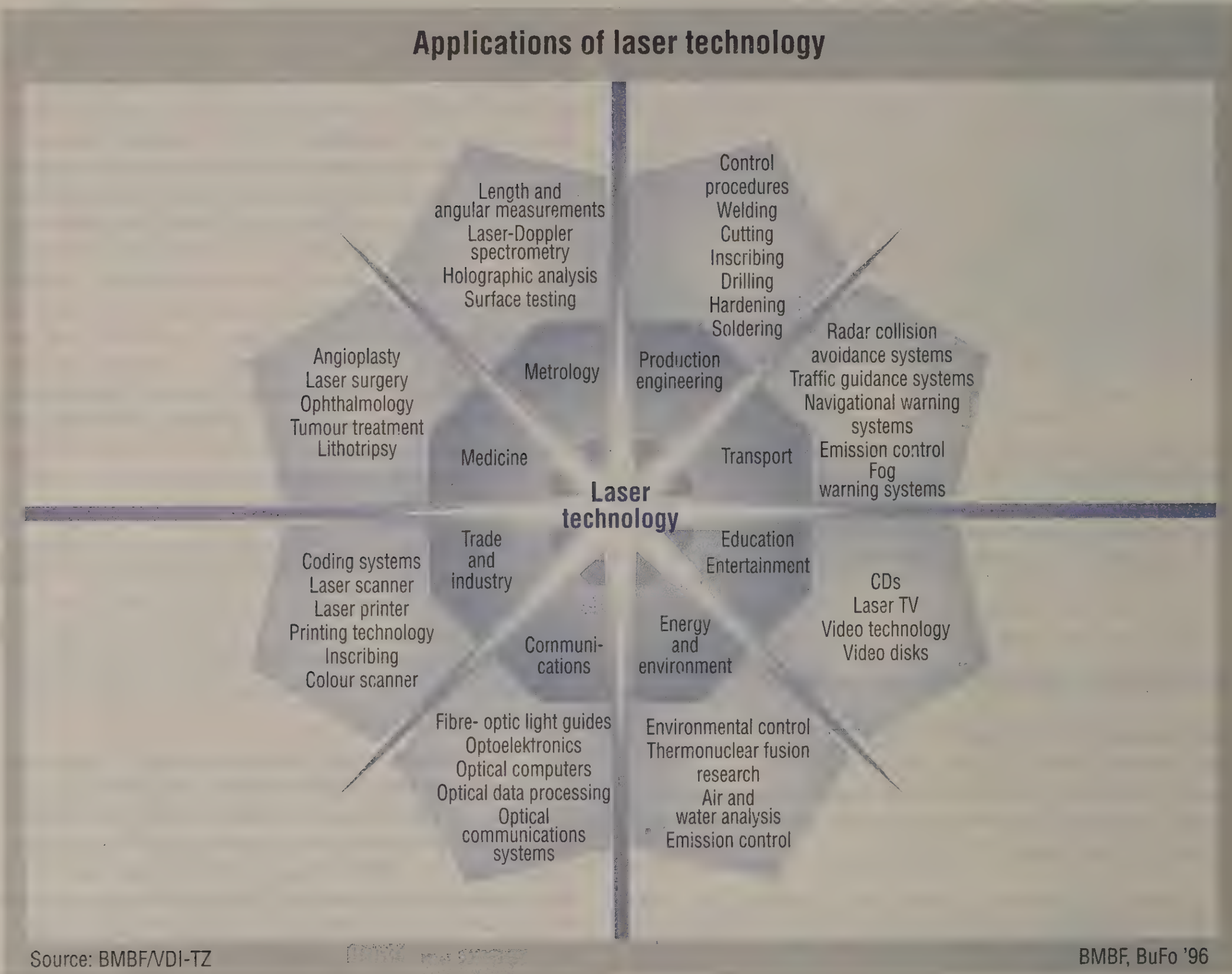
- With its "Services for the 21st century" initiative the Federal Government wants to contribute to tapping the still unexhausted innovation potentials of this sector. In particular, networks with industry-related services will be generated on the basis of a high technology oriented manufacturing sector. Services of this kind such as management consulting, market research, maintenance, training, personnel development and modern information and communications services have considerably contributed towards employment gains in Germany over the last ten years. These services now need to be developed further, taking into account their interdependence with and complementarity to the manufacturing sector. The aim is to make organisational boundaries between companies or corporate units more permeable so that new value added chains can be developed in flexible organisations. Only if it is possible to offer top-level services complementary to high technology will the tertiary sector grow also in Germany and produce appropriate employment gains.

4.2 No. 1 in Europe – opportunities for Germany offered by biosciences and biotechnology

The bioscience revolution

While it was primarily the progress achieved in physics, chemistry and the engineering sciences which helped shape today's industrialised society and technology, the 21st century will be determined mainly by the biosciences. The bioscience revolution is already in full swing. It was triggered by a quantum leap in the development of science, i.e. the discovery in the mid-1950s of the molecular structure of genetic mate-

Figure I/9



rial. This discovery has lead to completely new insights into the natural conditions and processes of life and hence man's ability to reconstruct and shape it. Even if many of the fears voiced publicly by critics today give a distorted picture of what has really been achieved, the very urgent question arises about the responsible use of the new possibilities. The necessary assessment and minimisation of potential risks does not fail to appreciate the tremendous opportunities offered by scientific progress; on the contrary, deciphering and utilising the blueprints of living nature open up new possibilities of learning from, and acting much more in accordance with, nature.

Biosciences are of key importance for medical progress. Molecular medicine is opening up realistic perspectives for treating diseases which so far have been considered incurable. In Germany more than 200,000 people die of cancer every year. The number of persons infected with the AIDS virus in Germany has by now risen to over 12,000 and more than 7,000 AIDS patients have already died. Fighting the causes of these diseases is not possible without modern molecular biology and biology using genetic engineering methods.

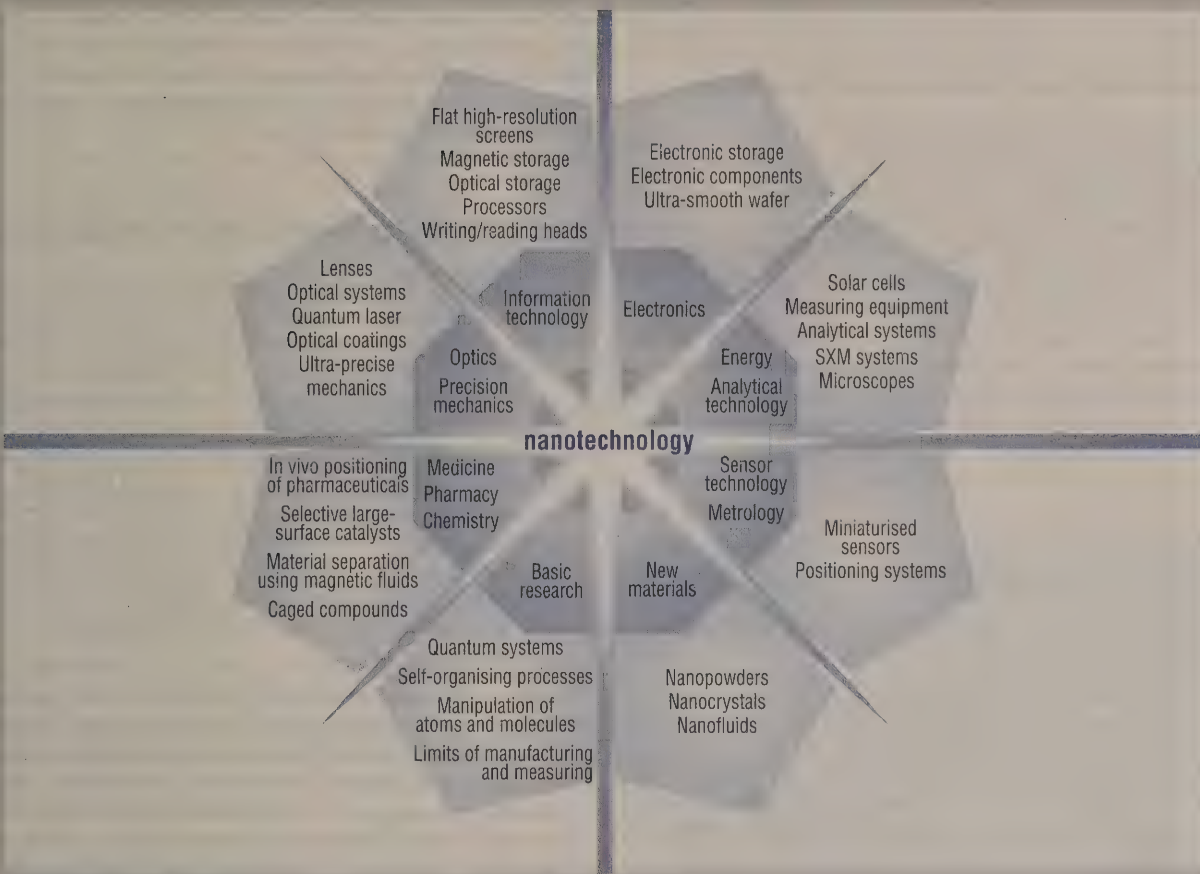
As much as two-thirds of all newly developed drugs today come from "biotech pipelines". Ten years ago it was only about 5 %. Current world market sales of the five most successful "genetically engineered" drugs total about DM 10 billion. In the future it will be possible to produce "individualised pharmaceuticals" tailored to the specific development of a disease in a particular patient.

Learning from nature

The more humanity unravels the mysteries of life the more it can use this newly gained knowledge for shaping its own future and that of nature. In the course of evolution living nature has developed highly-efficient processes for materials production and energy generation which can be used for industrial purposes. One example of a highly efficient and, at the same time, extremely complex system is the cell which may be regarded as the basic element of living nature. If its functional mechanism is deciphered, it may become the "chip" of biosciences. This means that the processing of information in cells can be used specifically e.g. for the natural formation, degradation or restructuring of substances.

Figure I/10

Applications of nanotechnology



Source: BMBF/VDI-TZ

BMBF, BuFo '96

Biotechnology also offers a great development potential for the environmental protection sector. Nature itself serves as a model. Optimised biological systems, usually micro-organisms and plants responsible for the natural cycle in the environment, can be used for ecologically sound, target-specific processes, e.g. for waste-water treatment, exhaust air cleaning or soil regeneration. By now waste-water treatment has become so successful in Germany that about 90 % of all households are connected to a biological waste-water treatment plant (compared with only 59 % in the USA and 64 % in France). "Soft" chemical processes based on biotechnological procedures not only help conserve resources and save energy, but also avoid the production of pollutants and enable residual substances to be recycled. A case in point is the use of enzymes for the production of active substances to be used e.g. in crop protectants.

Another important application of biotechnology is human nutrition. About 10 million people die of famine every year. It is therefore necessary to develop disease-resistant high-yield crop plants and extend the shelf-life of foodstuffs. In view of the growing world population it is vital to increase crop yields.

Biosciences also make it possible to improve the nutritional quality of foodstuffs, thus contributing to a healthier way of living. Breeding processes based on molecular biology, for example, help raise the vitamin or minerals content of foodstuffs, and modern biosensors can be used to determine the freshness of food or detect undesirable germs like salmonella at an early stage.

Bioscientific research concerning the possibilities of energy generation and raw material production is still in its infancy. Plant photosynthesis, in world-wide terms, is a gigantic production process which substantially increases the Earth's total supply of useful energy. Every year plants absorb about 700 billion tonnes of carbon dioxide from the atmosphere and the oceans and, using the sunlight, convert them into high-energy organic compounds like carbohydrates. In the search for renewable sources of energy it would therefore be obvious to apply genetic engineering processes in order to utilise – beyond the traditional scope – the enormous energy potential of photosynthesis, thus increasing the solar energy yield.

Biomass as a raw material can also play a more important role than before. In plant breeding, for example, genetic engineering could help produce certain raw materials or higher synthesis levels in an energy-saving, ecologically sound way. In such processes plants

are being used as bioreactors. A case in point is plants which produce the parent material for biodegradable plastics. As a result of this development the gross output of German agriculture might pick up again.

Opportunities and challenges in Germany

Recent independent international studies have confirmed Germany's good standing in the field of biosciences. The level of research is high in world-wide comparison. One proof of the high level of performances are the Nobel prizes which German scientists were awarded in recent years. Basic research in Germany has reached a high level that is based on an excellent advanced research and technology infrastructure. There are eight German institutes among the 50 molecular biology research institutions which had the highest number of citations world-wide between 1980 and 1991.

Future technological paths of biosciences

New paths which are being thoroughly studied at the moment include

- genome research: interpretation and utilisation of genetic information;
- functional biomolecular systems for technical use: development of biological solutions, especially for metrology and analytical technology;
- molecular test systems for natural substance research: targeted search for useful nutrients;
- cytobiology: research into, and utilisation of, cells as "elementary particles" of biology;
- evolutive biotechnology: technical implementation of the molecular evolutionary processes with a view to producing active substances;
- molecular plant breeding: increasing crop yields and quality.

In all these areas Germany has a highly qualified research potential which can be used for new technologies.

In spite of this excellent starting position industrial use in Germany has so far been modest:

- While in the USA the number of patent applications in the biosciences rose by approximately 120 % between 1987 and 1994, the increase was only about 16 % in Germany.
- While in the USA there were about 300 producing genetic engineering firms in 1994, it was only six in Germany.
- While in the USA there are currently about 1,300 biotechnology firms, it is 485 in the EU and fewer than 100 in Germany.

According to estimates made by industry the world market for such products and processes is developing at double-digit growth rates. The Senior Advisory Group for Biotechnology (SAGB) predicts that there will be a world market of about $ 100 billion by the year 2000, compared with $ 6 billion in 1991. This is why the Federal Government is doing everything in its power to prepare and equip Germany for this rapidly developing world market.

Areas of action for research and technology policy

Biotechnology is a crucial touchstone that will show whether Germany will continue to hold its internationally leading position and thus advance into innovative areas which open up new employment opportunities. To become the No. 1 in biotechnology in Europe is therefore the declared objective which the Federal Government is pursuing with a variety of schemes and measures. It is now essential to maintain powerful R&D capabilities and intensify the development of cooperations between science and industry. New ways and means need to be found in order considerably to improve the translation of research results into innovative products and processes:

- The interdisciplinary link between information technology and biotechnology will be developed further. This includes e.g. bioinformatics, algorithms from evolutive biotechnology and their application to complex problems as well as the simulation of image and voice processing of biological systems. These interdisciplinary projects are prepared by specialist meetings and implemented through target-specific measures.
- In order to achieve rapid progress in human genome research it is necessary to bring science and industry together to develop techniques for deciphering and utilising biological blueprints. The "Human genome research" pilot project provides for new structures in science and the involvement of industry right from the beginning. A network of agreements concluded between science and industry is intended to ensure close cooperation and across-the-board patenting of research results obtained by scientists.

Objectives of the German human genome project

- To accumulate knowledge of the structure and function of the human genome and the genomes of relevant model organisms through systematic genome analysis;
- to apply this knowledge with a view to fighting diseases more effectively with the aid of new diagnostics and therapies (welfare gains, economic advantages, new jobs);
- to clarify and uphold generally acceptable values (ethical, legal, social aspects of research).

- The "BioRegio" funding scheme is a new promotional approach designed as a contest between regions which are invited to submit integrated concepts for bioscientific research and the industrial implementation of the results obtained. This provides an incentive for regional cooperation among bioscientific research institutions in science and industry, venture capitalists, banks, funding organisations at the local level, licensing authorities and the like. The objective of this systemic approach is to make more efficient use of the material and intellectual potential, to encourage setting up new businesses and make Germany more attractive for investment by foreign entrepreneurs. A jury will select three regions with the most convincing BioRegio concepts which will then be given priority when the BMBF's funds are allocated.

- Developing and testing drugs and active ingredients of pharmaceuticals in Germany is vital for the further development of the health care system and as an asset of the German pharmaceutical industry. Clinical research and local expertise are indispensable prerequisites for preventing pharmaceutical companies from shifting their activities abroad. This implies that first of all the necessary structural basis has to be created. The scientific performance of German hospitals has to be in keeping with the quality awareness required in the world market today. Clinical research, patient care and teaching need to be better coordinated. These are objectives that are pursued by the "Centres for clinical studies" project.

- The "Somatic gene therapy" project has identified treatment methods for a wide range of medical complaints, including a number of diseases that have a high incidence and important economic effects, such as cancer, metabolic disorders as well as AIDS and other infectious diseases. Priority funding schemes are intended to advance highly innovative concepts of molecular medicine with clear clinical objectives. Close cooperation between theoretical, clinical and industrial working groups is required to transfer these approaches from basic research to practical medical care. Such an interdisciplinary approach to the issues involved is to be ensured by selective support of the cooperation between researchers of different disciplines and from pertinent industries.

- Further improvements in the legislation governing genetic engineering will be brought about by amending the pertinent overriding EU directives. Other laws also need to be examined for excessive administrative requirements.

- The Federal Government advocates the transparency of all bioscientific activities so that opportunities can be clearly identified and risks properly assessed. Only unrestricted disclosure of all findings will enable people to decide freely. Secrecy is counterproductive. This is why the Federal Government supports comprehensive, but practicable labelling of genetically modified foodstuffs.

- In 1996 the Council for Research, Technology and Innovation to the Federal Chancellor will focus on the opportunities offered to humanity by the biosciences and biotechnology as well as on the importance of such possibilities and their utilisation by science and industry. Germany's strengths and weaknesses in this area need to be identified. The Council will also address the possible risks that might arise from these technologies as well as the associated fears of the citizens.

4.3 Growth through knowledge: The future of the information society

On our way to the future

The "digital revolution"triggered by the precipitous development of information technology has quite rightly been likened to the fundamental change brought about by the industrial revolution in the last century. Acquisition, storage, processing, transfer, dissemination and utilisation of information and knowledge as well as interactive communication are possible in completely new dimensions and at great speed. Handling information has become *the* challenge – not only in economic, but also in cultural terms. Information networks are growing together world-wide and their user group is exploding. It is estimated that there are already more than 40 million Internet users world-wide. In the networks communi-

Economic perspectives of the information society

Translating information into knowledge opens up promising new perspectives for industry. Enormous growth potentials can be expected to emerge. Already today the information industry is the largest industrial sector next to the tourism industry. We are moving rapidely towards the information age. In 1960 there were about 9,000 computers world-wide, by the mid-1980s the number had risen to 50 million, in 1995 the count was about 110 million units. In Germany alone more than one million PCs are shipped every quarter. Today more computers than cars are sold world-wide. In 1993 the world market volume of information technology products and services was nearly DM 3,300 billion, with Germany accounting for DM 382 billion. Annual growth rates of up to 15 % are expected. Private applications such as digital encyclopaedias, video-on-demand and teleshopping represent a major growth area. Infotainment and edutainment introduce new ways of learning. New jobs such as information broker and information designer as well as audio-visual media designer will emerge in the service and information sectors. In 1994, as many as 1.4 million people were already working in the information industry.

cation and the acquisition of information are possible without any temporal or spatial barriers. The actual abode of the individual is irrelevant; all that is needed for living and working in cyberspace is access to the Internet. The world is growing together, the "global village" has long since ceased to be only a vision.

Never before have information and knowledge grown as fast as they do today. 90 % of all scientists that have ever lived on Earth are working today. Every workday 5,000 scientific papers are published world-wide. The knowledge available world-wide doubles every five to seven years. This knowledge potential can be used on-line through the neural network of the information highway.

Areas of application

Information as a raw material is becoming a crucial production factor. The management process itself is changing, bringing about new opportunities to fight increasing environmental pollution and the threat of scarce resources. Countries that successfully generate and disseminate information, efficiently implement knowledge and, in particular, use knowledge on a broad basis will enjoy a competitive edge. Systems know-how, knowledge-intensive manufacturing methods and control systems as well as intelligent services will improve the goods on offer while lowering the price. At the same time they reduce the raw material and energy input, are less material-intensive and hence ecologically sounder. In addition, modern information and communications technologies permit large-scale, long-term environmental monitoring as well as the interchange of environmental data. Thus a comprehensive picture can be gained of the condition of soil, water, air or climate. It is possible to identify undesirable trends at an earlier stage and take the necessary countermeasures. Transport telematics opens up the possibility of organising transport in a safe, efficient and environmentally acceptable manner. New telematics systems and new software concepts can lead to a homogeneous use of the transport infrastructure and a better linkage of the various modes of transport.

Telework can provide new incentives for creating new jobs. According to the Bangemann Report of the European Commission, the potential for telework jobs in Germany is around 800,000, a potential that is still far from being exhausted. Telework is also expected to bring about a 20 % gain in productivity as well as a higher competitiveness. At the same time, telework allows for a better reconciliation of family life and work. The separation of living and working is beginning to crumble. Working and manufacturing processes can be distributed and combined globally. The employees of virtual companies are linked with each other through data networks. In this way globally active groups can run their product development activities around the clock in different time zones, thus saving time and money.

The possibilities of telemaintenance, telediagnosis and telerepair are becoming more and more important. This means that manufacturers can monitor their machines without having to be physically present at the customer's plant. Observations concerning the operation and weak points of machines can be exchanged faster and more intensively between operator and manufacturer and new markets can be opened up, especially abroad. Fast and all-in service world-wide is indispensable today for companies which have to hold their own in the market. The combination of manufacturing and intelligent services can boost competitiveness decisively.

Modern information and communications technologies also offer numerous opportunities in the medical sector. Surgeons first practice complicated interventions on the screen before they operate on a patient. If necessary, they can get the support and advice of specialists from all over the world on the screen. They can also use modern control technologies. For the benefit of patients remotely controlled robots, for instance, can perform high-precision surgery on sensitive organs like the eye. They are much safer than even the steadiest of human hands. Modern information and communications technologies also help networkthe players in the health care system. Findings and therapies can be directly exchanged between, and discussed by, the physicians involved. Electronic patient monitoring can help save human lives when vital information can be made available fast.

New ways of teaching and learning will be possible in the information society. At the same time, new educational contents and new media skills are required. There will be new worlds of experience, but also new debates on the experience gained with new media. Media skills comprise more than just understanding the technical operating instructions. In the final analysis, media skills are the ability to handle the host of information and services offered, an ability which does not succumb to media laws, but is based on independent thinking and judgement.

Cultural reflexes are emerging. There will be more and more individualised newspapers and programmes. At the same time, communication will take on new forms and internationalise people's lives.

Opportunities and challenges – making multimedia possible

The first subject the Council for Research, Technology and Innovation to the Federal Chancellor focused on was the opportunities and challenges entailed by new information and communications technologies. The primary objective of the Council's work was to identify the opportunities offered by the new information technologies and also look at possible risks and problems which may be associated with the transition to the information society.

The main results of the deliberations held refer to the following areas:

- Restructuring telecommunications,
- creating a homogeneous regulatory framework,
- opening up new areas of applications for information and communications technologies,

German information society initiative

In the wake of the final report submitted by the Council for Research, Technology and Innovation the Federal Government launched the German information society initiative with a view to strengthening and improving Germany's position in research and development as well as in manufacturing and applying information technology products, systems and services. The German information society initiative is a signal for our transition towards the information society and our joint responsibility to shape this transition.

In its report **"Info 2000 – Germany's transition towards the information society" the Federal Government has outlined the measures it plans to take under this initiative.**

The report *takes stock* of the major technological, economic and societal developments in Germany and other countries and sets out the *objectives* as well as *an action plan of the Federal Government* for Germany's transition towards the information society. It takes into account the *recommendations presented by the Council for Research, Technology and Innovation to the Federal Chancellor,* outlining the following priorities:

- Obstacles to the transition towards the information society need to be removed: Creating a homogeneous legal framework for new information and communications services has priority.
- The population at large needs to adopt an open-minded attitude towards the information society: A dialogue forum will be set up where the most relevant groups of society will be represented.
- The information society requires the labour force to acquire new qualifications: For this reason the Federal Government will start a pro-active ‚education campaign' together with the Länder governments, the two sides of industry and all partners in the education system.
- The contribution by research and technological development is indispensable: A framework concept for research entitled ‚Innovations for the information society 1997 – 2002' is in the process of being developed.
- Modern information and communications technologies will make administration more efficient, improve its capacity to take quick action and bring it closer to the citizens: The Bonn/Berlin information network will be a model for innovative administration.
- It is especially in the information technology sector that norms and standards play a major role: This is why contents, organisation and procedures of European and international standardisation need to be adapted to the new requirements of the information society.
- Modern infrastructures require early and efficient international coordination: Priority has been given to dovetailing the policy of the Federal Government with the measures taken by the European Union as well as to embedding in the structures of international organisations the eight basic principles agreed upon by the G7 conference of ministers.

- teaching media skills at all levels of the education system,
- developing a high-speed information network for research and education,
- strengthening telecommunications and telework,
- electronic publishing and the digital library,
- multimedia applications as a key to administrative reform.

A central element of the "German information society initiative" is the legal framework. The telecommunications bill is resolutely aiming at creating a competitive situation in the telecommunications market. It will ensure that also in Germany modern and efficient telecommunications services will be offered at low prices. To enable Germany to maintain its competitive position and expand it in the future it is indispensable to allow the market forces to unfold swiftly in the area of multimedia services such as telebanking, teleshopping and video-on-demand. Investors intending to put millions into these new markets need a homogeneous, clear and reliable regulatory framework. This is why the creation of homogeneous legal conditions for new information and communications services has been given priority.

Fields of action of education, research and technology policy

Media and information skills, i.e. the active and responsible use of new multimedia possibilities, are playing a key role. What is needed is a broad-based pro-active education campaign comprising schools, higher education as well as vocational initial and continuing training. Fewer than 500 out of about 43,000 schools, for example, have access to the Internet, and computer places are available for only about 2 % of all pupils. With the "Connecting schools to the Internet" initiative the Federal Government, together with Deutsche Telekom, industry and the Länder governments, is working towards equipping a larger number of schools with computers, giving them access to the Internet and preparing them for an educationally meaningful use of the new technologies.

It is equally important to develop the multimedia capabilities of higher education institutions and offer them the opportunity to tap the world-wide pool of information and knowledge. The development decided upon by the Federal Government of a high-speed information network for research and education is already underway. This network will give universi-

ties, higher education institutions, Fachhochschulen and research institutes in Germany the opportunity to interconnect computers with a data transmission rate of 155 Mbit/s and use advanced multimedia techniques. It will also enable them to cooperate with research-oriented companies, chambers and technology transfer agencies.

The German information society initiative gives high priority to opening up new areas of application. To provide for the future it is necessary to promote research in the areas of basic technologies, application-oriented processes and development tools. To this end, the Federal Government is preparing a new "Innovations for the information society" funding programme. It will focus on high-resolution flat-screen monitors, reliable software technology and voice processing, concepts for virtual companies as well as standards for data interchange. These factors are expected to provide an important impetus for consolidating advantages in global competition and for productivity gains in the industrial and services sectors. The programme will be complemented by legislation conducive to innovations, grants for new businesses and schemes to raise risk capital as well as measures to increase technology acceptance, not least at the shopfloor level.

Another focus is on telecooperation and telework. The Federal Government has devised several projects to trigger developments in the private sector, mainly in areas with a great need for coordination such as the building industry. At the same time, other pilot projects will be launched, among them a project for the disabled to ensure that they can participate in working life on an equal basis. Finally, the subject of "teleservice" will be tackled in order to further the use of new information and communications technologies to improve telediagnosis, telemaintenance and telerepair and to contribute to opening up new markets.

The Federal Government also advocates the provision of a wide range of digitised information. This is why electronic publishing and the digital library are in the focus of the new "Scientific and technical information for the 21st century" programme. One of its aims is to shorten the interval between the development of a scientific result and its publication by using information and communications technologies. The other aim is to network the large number of information providers such as libraries and specialised information centres in order to ensure that publications can be made available without delay.

The international dimension of modern infrastructures requires an early and efficient international coordination of these measures. Top priority has been given to dovetailing the policy of the Federal Government with the measures taken by the European Union to chart Europe's transition towards the information society. The Federal Government also intends to base its national measures and decisions on the eight basic principles agreed upon by the G7 conference of ministers and to advocate embedding these principles in multilateral agreements concluded through international organisations – such as the OECD, WTO, WIPO and ITU – and enforcing them outside the G7 countries as well.

4.4 Energy and the environment:

Ensuring sustainable development on a permanent basis

Organising economic and social development in accordance with ecological resources is one of the central challenges characterising the decades to come. At the United Nations Conference on Environment and Development held in Rio de Janeiro in June 1992 the international community undertook to make sustainable development the basis of policy objectives.

"Sustainable development" is not a clear-cut instruction to act, but rather a model framework that needs to be fleshed out. Scientific research and technological development are called upon to improve our understanding of interactions in the biosphere as well as to develop fundamental problem solutions designed to reduce environmental pollution. It is the objective of the Federal Government's policy to organise economic and social progress in such a way that natural resources and the ecological balance are ensured on a permanent basis. The reorientation of the previous energy and environmental research programmes is a strategic contribution to achieving this objective.

The guiding principle of sustainability broadens the horizon of environmental research. The object of research is not the isolated "environment" system alone, but the interactions between ecological, economic and social developments.

Ensuring sustainability through research

Environmental research is not only about deepening the understanding of complex systems, but also about the adequate translation of scientific results into political and economic action. In this context, the development of environmental quality targets, indicators and assessment procedures which take into account both ecological and socio-economic requirements is of particular importance.

There are three major areas where new knowledge needs to be generated, new technologies developed and policy concepts drafted:

- **Safeguarding natural resources**

  So far it has proved very difficult to make a sufficiently reliable assessment of the future development of long-term global changes and their impact. For this reason research on ecological sustainability aims to create a better understanding of environmental systems themselves, i.e. the climate systems, the terrestrial ecosystems, the forests, the urban-industrial spaces, agrarian landscapes as well as river and lake environments.

  One of the central tasks of climate systems research is the complete modelling of the impact of human activities on the climate and – conversely – the repercussions of climate changes on the human habitat. New differentiated questions such as the local

and temporal variability of the climate and its effects on the hydrological cycle are moving into focus. Today we know that as the climate changes the frequency of extreme weather events increases. The knowledge of regional effects of climate change needs to be deepened so that targeted and effective preventive action can be taken, e.g. in the area of flood control.

In special weather situations the effects of atmospheric pollutants can be felt immediately. Here it is a major task of research to improve the basis for medium- and long-term forecasts by creating a better understanding of the systems involved and concentrating on process investigation, variability and predictability. This is an indispensable prerequisite for the environmental assessment of air pollution and the evaluation of preventive strategies.

Research on ecological sustainability is not limited to climate and atmospheric research. In recent years another interdisciplinary approach of environmental research has gained in importance, i.e. a land-use oriented research approach which develops utilisation, organisational and clean-up concepts for living spaces and economic areas (cultivated landscapes). Cases in point are the renaturation of rivers and lakes and the recultivation of surface-mined land.

– **Sustainable management**

As important as the perspective directed at the natural habitat are findings that help change economic and social structures as well as patterns of action and behaviour in such a way that sustainable, ecologically sound management and living are possible.

The Enquete Commission on the "Protection of Humanity and the Environment" formulated some fundamental rules for the cost-effective and sustainable management of natural resources:

- The depletion rates of renewable resources should not exceed their renewal rates.
- Consumption of non-renewable resources should be limited to levels at which they can either be replaced by physically or functionally equivalent renewable resources or at which consumption can be offset by increasing the productivity of renewable or non-renewable resources.
- Inputs of substances to the environment should be oriented towards the maximum absorption capacity of environmental media.
- There must be a balanced ratio between the time scale of man-made inputs to, or interventions in, the environment and the time scale of the natural processes which are relevant for the reaction capacity of the environment.

Technical innovations will continue to be the main pillar of sustainable management. Environmental technology must develop and improve the expected technical solutions for wastewater and sludge treatment, for reducing soil, water and air pollution, for cleaning up contaminated sites and for noise reduction so that immediate effective countermeasures can be taken in those cases where ecological limits have already been exceeded.

Technical products and services designed to protect the environment are gaining more and more economic importance. Their rating in the world markets will increase considerably. As a provider of high-quality environmental technologies Germany is among the front runners.

To strengthen our competitiveness and, at the same time, reduce environmental pollution further innovations are needed in the technical, economic and social areas. One of the central objectives is 'clean production'. To this end, down-stream end-of-pipe technologies have to be complemented and replaced by integrated solutions which do not give rise to undesirable environmental pollution in the first place. In this context, *product-integrated and production-integrated environmental protection* is playing a key role. The object of this innovative research approach is the entire chain from raw material use to processing, manufacture and use of a product to its return into the product cycle. Successful examples are the development of effluent-free nickel-chromium plants (electroplating plants) as well as environmentally compatible pulp production and chlorine-free paper bleaching.

– **General setting for ecologically sound action**

Research on sustainable management sheds light on the interactions between humanity and the environment. With his behaviour and also to satisfy basic needs like eating, housing, mobility and leisure man interferes with nature and at the same time is affected himself by man-made environmental pollution.

Research focuses on the assessment of health hazards caused by environmental chemicals and other environmental factors such as increased UV-B irradiation as well as on the exploration of measures that can be taken to avoid such pollution. Toxicological methods of assessing the risk of substances that may constitute a health hazard as well as epidemiological studies provide the basis for evaluating and determining environmental targets.

Research must contribute to devising an adequate framework. This includes developing new approaches in environmental education which broaden the basis for future ecologically sound human action. Another objective is to test and improve governmental tools for realising sustainable development.

In recent years knowledge of the environment has increased dramatically world-wide owing to, among other things, new research capacities cre-

ated by the Federal Government and greater funds allocated to environmental research. The challenge now is to apply this knowledge.

Energy – charting the course to sustainable development

World-wide the supply of low-cost energy is a major prerequisite for trade and industry to meet the needs of a growing population. But at present the generation, distribution and use of energy still cause severe environmental pollution. For example, energy generation today contributes about one-third to world-wide man-made climate change. At the same time, sustainable development in other areas is inconceivable without a secure low-cost energy supply.

For this reason the CO_2 reduction programme of the Federal Government which is aiming to lower CO_2 emissions to 25 % below the 1990 level by the year 2005 is a particular challenge to the overall system of energy generation, supply and use. Over the last 20 years Germany has succeeded in separating the increasing primary energy consumption from GNP growth. To reach the targets of the CO_2 reduction programme additional savings and efficiency potentials need to be realised which rely on an enhanced use of knowledge, innovative technologies and creative ideas for implementation.

There is a variety of conceivable research approaches; but their realisation, taking into account economic implications as well, calls for a careful selection of the technologies to be funded as well as a growing commitment by industry. The dialogue with all those concerned must be continued so that a joint long-term strategy for the research and development of new energy technologies can be devised.

> To reduce CO_2 emissions **energy conservation technologies** will be most effective in the medium term, i.e. until 2005 to 2010. This applies to power generation using fossil energy sources (including co-generation), the provision of space heating, industrial processes and the transport sector. But when it comes to lighting, electricity and telecommunications in private households and to areas where energy consumption in general is relatively low such technologies are less effective. On the **energy supply** side nuclear energy is indispensable for sustained CO_2 reductions. In the short and medium term the contribution of renewable energies to total energy supply is likely to be small, unless it is based on hydropower or waste incineration. It also relies on wind energy and biomass.
>
> In the long term, i.e. between 2010 to 2030, renewable energy sources, especially biomass, solar thermal power and photovoltaics as well as new technologies for secondary energies such as hydrogen and fuel cells can and must gain greater importance.

The most important potentials available for achieving the CO_2 reduction target include the use of modern power plant technologies for fossil-fuelled power stations, space heating of buildings and the application of new technologies in industry and the transport sector. Major progress in these areas depends not only on energy research, but also – to a quite considerable extent – on developments in other areas such as microelectronics, computer science or materials sciences. This is why these areas need to be covered more by energy research and included in more comprehensive pilot projects.

Photovoltaics has by now reached a high technical level. If photovoltaics is to make a major contribution to energy supply in Germany in the long term, its costs need to be reduced considerably. This means that its efficiency has to be increased, systems and manufacturing techniques improved and solutions found for integrating more photovoltaic systems at low cost in roofs and facades of new and existing buildings. Already today photovoltaics is playing an important role in high-tech products where either electricity supply costs are not a crucial factor or an off-the line power source offers great advantages.

The development of wind energy which is funded by the government has reached a high technological level in Germany and is now making such a substantial contribution to total electricity supply that future research efforts can be concentrated on a few issues only that are still open.

From the current point of view nuclear energy offers one of the greatest potentials for preventing CO_2 emissions. In Germany it is an essential component of the energy supply mix. Virtually all major industrialised nations in the world use nuclear energy to ensure their electricity supply. So if Germany wants to influence international development with a view to enhancing safety, it will have to come first in the world league in reactor safety. This not only implies that it will have to operate its own reactors in an exemplary way, but also that it will have to support independent safety research.

Controlled thermonuclear fusion represents a long-term option for tapping a new CO_2-free energy source. Experts expect that it will not be possible before the year 2050 to operate a commercial fusion reactor to generate energy. This is why thermonuclear fusion research is a task which requires international cooperation and hence has to be based on a broad consensus concerning future development lines and projects.

4.5 Mobility – decoupling growth and economic resource consumption

Human mobility – defined as the need and ability to move from one place to another – has increased continuously over the last years and centuries. One indicator of mobility is the number of kilometres travelled by a person per year: Whereas 200 years ago the average mileage of a person was about 100 km per year, it was already just under 1,000 km at the beginning of this century, and today mobility has reached a

Development of mobility and transport into the next millennium

The Single European Market, the restructuring of Europe and – not least – German unification have created both the basis for, and the necessity of, greater integration of European passenger and goods transport. As in other countries, the importance of transport in Germany is reflected in substantially increased passenger and goods transport volumes. Future economic development in Germany and Europe will make transport grow even more and increase the distances to be covered. In addition to previously dominating domestic transport, transfrontier traffic and transit traffic, e.g. to the newly emerging markets in the East, will become more and more important.

A future-oriented transport and mobility policy needs forecasts of the transport volume to be expected in the future as well as of the breakdown of this volume by transport mode. Obviously, such forecasts depend strongly on the predicted economic development and hence are in part an extrapolation of the previous development. They are also determined by expected changes in the economic structure, the segmentation of markets, the breakdown of goods transport by commodity, the predicted demographic development as well as the future mobility behaviour of the population in the areas of commuter transport, shopping and recreational traffic as well as holiday traffic.

In recent years transport development forecasts were made, for instance, when the Federal Traffic Infrastructure Plan was drafted as well as in investigations conducted by the DIW (1994) and studies by the Ifo Institute (1995). Obviously, such forecasts have a certain bandwidth of results, depending on the base year, the target year and the given general setting. The essential point is that fundamental developments are assessed similarly in different forecasts. In the following results of the DIW forecast made in the context of the ‚Ikarus' project will be presented to illustrate the expected development.

Goods transport

Forecasts of goods transport generally expect an above-average growth of road transport, i.e. that in 2020 road haulage would have a larger share in total transport than today, while the shares of rail transport and inland shipping would shrink in relative terms, although their volume would grow in absolute terms. Among the reasons given for this development are the expected intensification of trade relations with Eastern Europe and a strong rise in transfrontier traffic. Generally, growing transport volumes and increasing mean distances will lead to another rise in transport performance (the product of the volume of freight transported and the distances covered) which can only in part be absorbed by the rationalisation efforts identifiable so far in freight transport, e.g. a more efficient use of vehicles (reducing the number of empty trips) and shifting effects.

Passenger transport

The growth rates in passenger transport are attributed, among other things, to a future higher passenger car availability (cars per inhabitant) and a proportionately declining passenger car occupancy rate as well as an increasing number of travel purposes, e.g. business travels, recreational and holiday trips, and longer mean distances. It is expected that private car transport and air traffic will at first be the main contributors to rising passenger transport, while railways and local public passenger transport can realise their potentials only slowly.

level of 10,000 km per capita per year. Forecasts predict another increase of up to 40 % by the year 2005.

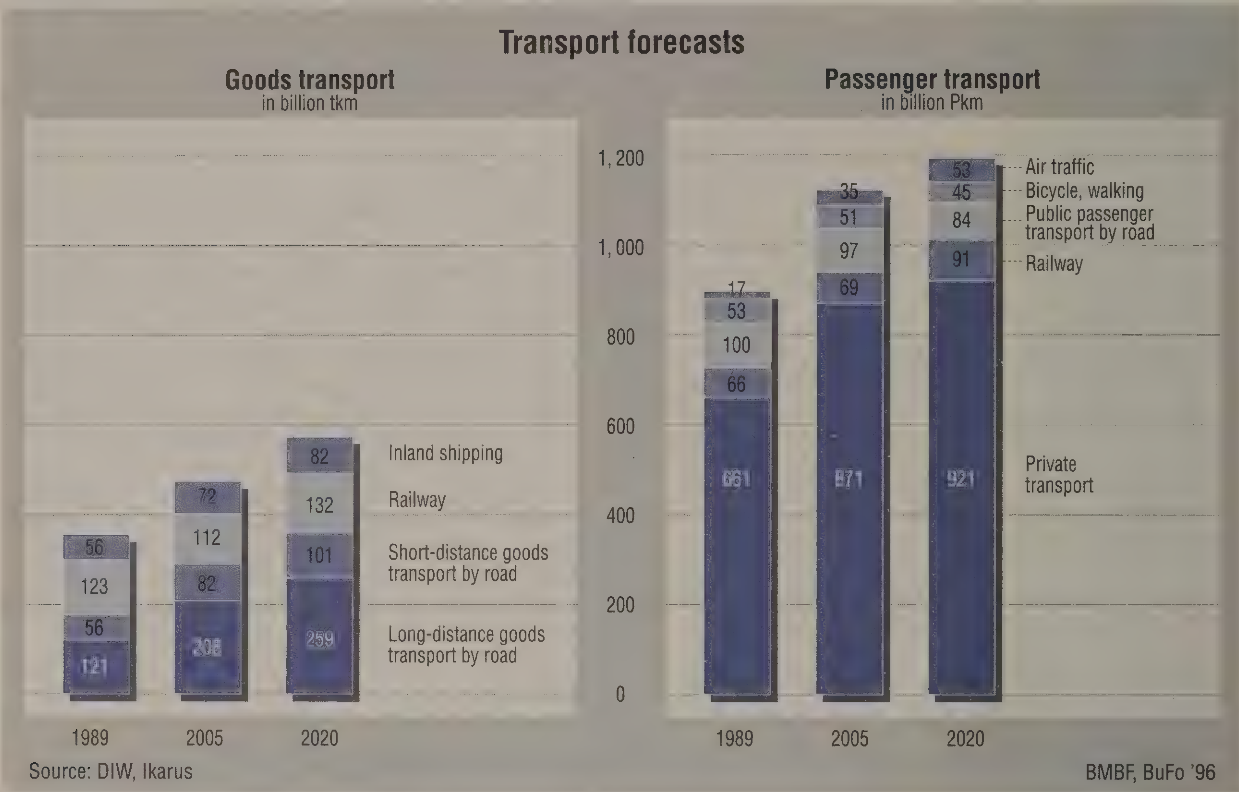
Not only the mobility of persons, but also that of goods has risen dramatically in recent years. The mobility of goods has become a central economic factor and an indispensable prerequisite for our industrialised society built on division of labour. In Germany, about 2.3 million people are working in the transport sector today, about half of them in vehicle construction and the other half in the transport services area. Accordingly, the transport sector accounts for about 7.5 % of German GDP. This does not include employees of insurance companies, parts of public administration and the waste management sector. The macroeconomic net contribution of the transport sector to value added in Germany is between 15 % and 20 %.

In Germany so far growth in the transport sector has been a concomitant of increasing prosperity. In the past the total transport volume has developed almost parallel to GDP. In the future it will be necessary to separate growth and the consumption of resources, i.e. to continue to maintain the necessary aspect of transport, viz. the transport capacity, to guarantee economic development and prosperity. But at the same it must be ensured that the more negative effects of transport, especially emissions and distances travelled, are reduced so that the cost-benefit ratio in the transport sector can be clearly improved due to a tangible increase in transport efficiency. Over the last 20 years this separation has already been implemented with some success in freight transport. In addition, better coordination of transport and housing development plans can help reduce unnecessary traffic, particularly on a regional scale.

Mobility of the future – the future of mobility

Even today the dimensions of future mobility can be described in rather concrete scenarios:

Figure I/11



- Shipping machinery and equipment from a factory in Spain to a little town in Germany is fast and inexpensive due to combined transport. Transshipment from water to rail for overnight rail transport and then to the road for delivery by special city truck takes place at transhipment terminals. It is not necessary to change to other transport containers. The forwarder will know at any time where the goods carried are and in what condition they are.

- In the areas of personal mobility transition from one mode of transport to another will become more user-friendly. Using a chip card the traveller of the future will drive to the railway station in his hired city car, leave it there and travel to his destination in a high-speed train; there he will use local public passenger transport (or take a taxi) to get to the hotel into which he has been booked. All payments can also be made European-wide with a single chip card. Before leaving the traveller will have consulted his PTA (Personal Trip Assistant) to get up-to-date traffic news and information of traffic jams and confirm his hotel booking. The PTA will have suggested that he take the train in view of the road traffic situation, providing information on the best train connections.

In such scenarios the realisation of necessary mobility in private life as well as for business purposes is combined with a much more ecologically sound and comfortable organisation of transport. The various transport modes will have been combined to form a flexible overall transport system which the individual can use fast and without any major loss of time.

Integrative transport concepts will only make a breakthrough after demonstration projects involving new technologies and innovative transport management have provided practical evidence that networking air, water, rail and road transport will improve the overall quality of goods and passenger transport. Such pilot projects will only be successful if they are attractive for users and lucrative for businesses. This also implies that basic conditions as defined by the government and the organisational structure are conducive to innovation and that uniform standards are developed to provide the necessary basis for the implementation of the results obtained. In view of the great diversity of interests involved (local and Länder governments, suppliers, operators, users) the Federal Government has to play an important role as a facilitator.

Federal research strategies for the future organisation of mobility and transport

The main challenge for the transport system of the future is to reconcile growing transport needs and environmental protection as well as operative physical and settlement structures.

The task of research and development is to create the basis for an integrated overall transport concept which provides for the mobility of persons and the transport of goods in a safe and efficient manner. At the same time it has to ensure a maximum of environmental compatibility, increase the quality of life and maintain the attraction of Germany in interna-

tional competition. In this context funding application-oriented developments and pilot projects is of particular importance.

R&D activities will therefore focus on the improved networking and linking of the various modes of transport, i.e. road, rail, water and air, to form an efficient overall transport system in which the transport modes interact in a coordinated way. Modern communications, guidance and information technology systems, known under the comprehensive term of 'telematics', will create the necessary basis. This is why they will have to be designed as interoperable systems and comply with homogeneous standards, also at the European level, so that they can effectively complement and support future innovative and regulatory measures. Only then can passenger and goods transport sequences be based on a division of labour ensuring that the specific strengths of the individual mode of transport can be fully exploited for particular transport purposes. Improved management of individual transport systems and modes as well as organisation of traffic flows across the systems create the basis as well as incentives for shifting traffic to modes of transport that are not used to full capacity and/or are ecologically sounder. Since the use of telematics systems and services represents a significant future market for industry, it is primarily the industrial sector that is called upon to push developments in this field.

In passenger transport the attraction and user-friendliness of public transport need to be enhanced and the interfaces between railways, trams and busses as well as between private and public transport improved in order to create a more favourable setting for shifting the choice of transport in favour of local and long-distance public transport. Local public passenger transport needs modern transport systems which permit low-cost operation in metropolitan areas.

In goods transport it is also necessary to reduce the resistance to shifting between various transport modes and organise fast and cost-effective transshipment, using intelligent technologies. With the railway reform the Federal Government has created an essential regulatory and investment framework for the more extensive use of rail transport. Now new efficient technologies are needed to support train composition, control and tracking, the drive concepts, transshipment operations as well as the logistic links with forwarders and shippers. In addition, open information and communications systems have to be used for transport handling and monitoring so that transport chains can be adequately complemented by information chains. The objective of transport policy in this respect is to make freight transport by rail, in cooperation with the forwarders and the shipping industry, so efficient that "intermodal transport" can achieve a disproportionately high share in goods transport growth. Special attention needs to be given to integrating inland and coastal shipping, because there is a large potential of free and ecologically sound transport capacities. It will be important to support concepts, together with industry, which seem to be most suitable for later implementation.

The capacities of existing transport systems and infrastructures, however, also need to be modernised and utilised to full advantage.

City traffic would be eased considerably if suitable guidance and information systems made the search for a destination or a free parking space easier. On the motorways and in rail, water and air transport intelligent guidance systems could also improve and accelerate traffic flows. Electronic fleet and capacity management enable the optimal utilisation of vehicles with a view to generating less traffic. This could lead to substantial cost savings.

The further development of telecommunications, teleservices and telecooperation can contribute to substitute physical traffic with data traffic and to cut off traffic peaks.

Reducing environmental pollution and resource consumption by innovative vehicle manufacture and operation is a direct challenge to research and development. Only if energy consumption and pollutant emissions can be cut down dramatically will future generations have the opportunity to stay mobile. The most important tasks in this area are to improve conventional propulsion systems and develop new ones, reducing vehicle weight by using new materials and processes as well as improving aerodynamics and acoustics. In the medium term measures designed to cut energy consumption will certainly make a greater contribution to reducing the environmental pollution than the use of renewable energy sources. But in the long term alternative energy and drive concepts will contribute much more to solving energy supply and environmental problems. It is the task of research policy to assess the maturity and development potential of the various alternative energy and propulsion concepts as well as of the possible energy generation alternatives and, where possible, promote and support them and make sure that the political setting is conducive to their use.

Another objective is the development of ecologically sound vehicle manufacturing processes and recycling-driven design and construction with a view to realising a closed circuit, wherever possible.

Despite the great success achieved in recent years the still exorbitantly high number of road deaths and casualties shows that increasing road safety continues to be a priority. Starting points of road safety research are active and passive vehicle safety systems as well as road infrastructure.

It is important that in the future mobility and factors that generate traffic as well as their interactions are better understood. This is why transport systems research is to be intensified at both universities and non-university research institutions. Traffic is the immediate consequence of human social and economic activities and it is influenced by changing social, economic and technological factors. The better these interactions are understood, the more sound and reliable the forecasts of transport development will be as a basis for future transport concepts.

4.6 Competitiveness through international cooperation

Objectives of cooperation with other countries in research and technology

International cooperation in research and technology is one of the main pillars of Germany's international relations. It has always made an important contribution to attaining political priority objectives, e.g. by providing aid for third world countries and supporting peaceful change in Central and Eastern Europe as well as the Middle East. The interests and objectives that arise immediately from the perspective of research and technology policy are also of great importance. They comprise

- cooperation including the transfer of know-how for the mutual benefit of the parties involved and for strengthening Germany's position as a location for research and technology;
- scientific and technical cooperation as the basis of intensified economic relations; support of German companies in markets of the future;
- solution of important current problems arising e.g. in environmental sciences and geosciences which can only be solved in international cooperation;
- pooling of intellectual resources available worldwide as well as an international division of labour in order to tackle highly complex research tasks, e.g. in genome and climate research, with the prospect of success;
- cost sharing, e.g. in the case of large-scale equipment and research infrastructure (e.g. for high-energy physics, thermonuclear fusion, space flight) whose financing would exceed the financial strength even of larger countries;
- meaningful complementation of national German research programmes.

Germany must strive to remain a location that is recognised not only in Europe, but world-wide as a place where the results of innovative research and technology development are not only generated, but also applied. International openness and the ability to cooperate are prerequisites which are strengthened e.g. by the mobility of researchers and the experience that young scientists gather abroad.

For this reason the Federal Government supports the exchange of individuals, e.g. within the framework of university twinnings and under programmes for individual higher-level qualification. Under such schemes about 47,000 German students and scientists went abroad in 1994, with 12,000 being supported by EU funds. In the same year resources were appropriated for the stay in Germany of 23,000 foreign students and scientists.

In competition-driven industrialised countries cooperation makes particular sense in those cases where identical interests and complementary skills promise faster and better results and – not least – substantial cost savings. This is why the focus is on large-scale projects based on a division of labour (e.g. space research), research projects that are in the public interest (such as health research) and basic research. More and more cooperative projects with industrialised countries are conducted within the framework of multilateral activities.

In view of the economic importance which scientific and technical cooperation has gained the Federal Government intends to strengthen scientific and technological relations with those non-European countries

- whose companies are looking for production or research sites in Europe and for whom the solid R&D basis that Germany can offer is an additional incentive for investment;
- with whom closer cooperation in science, research and technology also opens up opportunities for exporting German high technology or sophisticated products, be it to the country in question or to an even larger market;
- where the commitment of German scientists would have a favourable influence on economic relations as well.

In the case of developing countries cooperation traditionally focuses on developing an appropriate scientific and technical infrastructure as well as on applying technologies adapted to local conditions. Sizeable groups of outstanding scientists and engineers have formed and a substantial number of first-class laboratories has developed in quite a few of Germany's partner countries of many years which today rank among the newly industrialised countries. This situation, in combination with a dynamic economic development in these countries, now offers a good opportunity to intensify economic relations (cf. Part V, Section 2.1.5).

Instruments and dimensions of cooperation in research and technology

Patterns of cooperation range from bilateral agreements and projects to the coordination of national research projects with one or several countries to far-reaching consultations within the EU framework (cf. Part V, Section 1).

Germany is engaged in close and intensive cooperation with European states in many different ways. These are in particular

- the programmes of the EU for research, technological development and innovation,
- the multilateral EUREKA and COST cooperative frameworks,
- established cooperation in setting up and operating special large-scale equipment and jointly financed research institutions or organisations.

In the Organisation for Economic Cooperation and Development (OECD) the Federal Republic of Germany cooperates within a multilateral framework. In the OECD's "Mega-Science Forum" the governments of the member states consult about major projects and programmes. Germany will participate in

working groups on neutron sources, access to large-scale equipment as well as legal and administrative obstacles to cooperation. These activities, however, have to be regarded as subsidiary to the formation of opinion in the scientific community proper. The Federal Government expects that its participation will facilitate future joint projects developed by science as well as lead to a pooling of resources.

Today bilateral collaboration with individual partner states is still characteristic of scientific and technical cooperation with non-European countries. However, major international research programmes such as the Human Frontier Science Programme (HFSP), the International Geosphere-Biosphere Programme (IGBP) and the World Climate Research Programme (WCRP) are becoming more and more important.

European approaches and perspectives

The EU is at the centre of cooperation with European countries in research and technology. In 1995 the Fourth EU Framework Programme on Research and Technological Development and the EURATOM Framework Programme were started which will both run until 1998. About DM 24.7 billion has been earmarked for these programmes until they end in 1998.

Research in the Federal Republic of Germany will benefit from the European research programmes:

- Networking and developing European partnerships, a process which is specifically supported by the EU, will also broaden the basis for German research and industry in international competition;
- in key areas such as microelectronics and telecommunications European programmes have considerably helped Germany catch up in world-wide competition or defend its leading position;
- in fusion research the top positions held by Germany and Europe are the result of the European thermonuclear fusion programme;
- European environmental research owes its high standard to European-wide promotion and funding;
- the European innovation programme contributes to networking the innovation systems of the member states.

The Fourth Framework Programme (including EURATOM) can build on the positive experience gained with earlier framework programmes. This is the first time that all R&D activities of the Community have been integrated into one programme which, in addition, contains important new components such as

- target-specific support of SMEs in all parts of the programme,
- stronger support of other policy areas, e.g. by focusing on themes like transport research and biomedicine,
- improving the basis for the further societal development of the Community by funding socio-economic research,
- encouraging and funding innovation.

It is now essential to use this basis to take advantage of the new opportunities opening up in Europe and successfully take up the new challenges. The activities that this involves in particular are

- to prepare Europe even more effectively than before for world-wide technological competition, thus protecting jobs and developing prosperity;
- to ensure the basis for front-line research and the development of innovative technologies through an optimal infrastructure and a sufficiently flexible general setting;
- to provide sustained support – also on the part of the EU – for the development of Eastern and Central European countries, thus paving their way into the Community;
- to take on Europe's growing international responsibility, especially vis-à-vis neighbouring regions like the CIS countries and the Mediterranean region.

This is why the Federal Government welcomes the initiative of the Commission to focus European research funding more than before on topical issues which are of strategic importance for Europe's overall development. Since spring 1995 the EU Commission has been setting up task forces to deal with subjects like aircraft of the future, combined transport, vaccines/viral diseases, educational multimedia software and environmental technology/water which in intensive consultation with industry and science develop concepts for strategic initiatives. Focusing on key projects may be an important step towards increasing the weight of European research funding.

The principle underlying European research funding, which gives the Framework Programme its European profile, is the focus on key issues, taking advantage of the strengths of European science and industry; at the same time, and in the interest of European integration, an adequate range of issues needs to be covered and the principle of subsidiarity to be complied with. It would be impossible to generate value added at the European level if the EU Framework Programme had the sole purpose of closing financial gaps in the various national R&D programmes.

Concentrating more on key issues will also considerably help coordinate European research funding and national programmes from the subsidiarity angle. The "Coordination of Community and national R&D policies" is a result of the Federal Government's initiative taken during its presidency in the second half of 1994. During the first six months of 1995 the Council, under French presidency, took the necessary policy decisions. The challenge now is to centre the draft of the Fifth EU Framework Programme on priorities with a pan-European dimension.

The Federal Government welcomes the increased importance of EU research funding. But it is because of this greater importance in particular that the Federal Government advocates a stronger integration of science itself into the deliberation and decision-making process of the EU Commission; it also supports the

decentralised implementation of programmes, where possible. In some cases this may result in shorter distances, greater local presence and hence increased efficiency.

As well as EU research funding the decentralised cooperation mechanisms EUREKA and COST are of special importance:

- In addition to direct research funding by the EU, EUREKA is an important instrument for creating a European technology community. With its large membership (24 European states and the EU), its inviting attitude towards Central and Eastern Europe, its project-related and application-oriented approach and fundamental openness for participation by third countries EUREKA offers a suitable platform for European cooperation, especially in the business enterprise sector. Making better use of the EUREKA cooperation framework to define demand-driven research themes within the European specialised programmes will become more and more important, especially in view of the planned concentration of EU research funding.
- Providing a framework for the coordination of European science and research, COST concentrates its activities on basic research and research that is either in the public interest or still in the pre-competitive phase. Since it is flexible enough to integrate Central and Eastern European countries at an early stage COST has acquired a specific integrative function in the completion of Europe that will continue to be needed in the next few years. As direct European research funding will be more concentrated, COST can play a special role in developing new themes which may be considered later when Community programmes are updated.

European space flight

As well as the German national programme the European Space Agency, ESA, constitutes an important instrument of German space policy. Based on a Franco-German agreement on policy issues, decisions could be taken in October 1995 which were necessary to ensure Europe's independent access to space and strengthen its skills and competence as a cooperation partner of other nations that are leading in space technology. German participation in the International Space Station project underscores this intention. The European Ariane launcher which, being the leader in the world market for commercial satellite launches, holds a market share of about 60 %, as well as the successful launch of ERS 2, the European Earth Resources Satellite, are representative of the success of European cooperation in the space flight sector.

Cooperation in the large-scale equipment sector

The fourth important component of European research is cooperation in setting up and operating large-scale equipment which has been thriving for decades. Defining cooperation on a case-by-case basis has proved to be a success. The decision to build the Large Hadron Collider, LHC, at CERN, commissioning the synchrotron radiation facility, ESRF, in 1994 and recommissioning the ILL very-high flux reactor in Grenoble are positive examples of the successful development of a "Europe of research". The Federal Government is pressing for third countries like the USA, Japan, Canada and Russia to participate in the LHC project in order to optimise both time of construction and equipment.

Priorities of regional cooperation outside Europe

A top priority among bilateral relations is cooperation with Israel which has been flourishing for over 30 years. The pillars of this cooperation are the German-Israeli Foundation for Scientific Research and Development (GIF), the funding of German-Israeli cooperation centres through the Minerva Stiftung Gesellschaft für die Forschung mbH as well as the research projects financed directly by the two national research ministries. The German-Israeli Cooperation Council for High and Environmental Technologies (DIKHUT) which was instituted in 1995 is expected to provide an additional strong thrust.

In adopting its Asia and Latin America concepts the Federal Government has made it quite clear that it intends to support development in these regions by means of a homogeneous and coordinated policy. Scientific and technical cooperation is a major element of these concepts. The BMBF's 'Concept for scientific and technical cooperation with Asian-Pacific countries' was published on 20 October 1995, another concept for cooperation with Latin America is in the process of being drafted. The main objective is to take advantage of the cooperation experience which in some cases dates back more than 20 years, with a view to

- bringing Germany's industrial, scientific and technological capacities together with the needs and possibilities of those countries and making an adequate contribution to developing their potential;
- strengthening the joint awareness of ecological risks, pushing technological and economic solutions and opening up new markets;
- meeting the great demand for qualified educational services by offering suitable schemes in Germany because this is indispensable for the long-term cultivation of cultural, scientific and economic relations;
- better understanding the dynamic developments and cultural conditions in these regions and educating the German public accordingly.

In this spirit the BMBF will intensify project cooperation in the areas of technologies of the future. In education and training this is complemented by concentrated efforts to intensify exchange. In the interest of cultivating relations on a long-term basis it is necessary in those regions to revive interest in university studies in Germany (cf. Part V, Section 2.1.2).

In February 1996 the decision was taken to open the Science and Technology Office in Shanghai which

constitutes an important element of the Federal Government's Asia concept. Funded by the Fraunhofer Society, the German Aerospace Research Establishment, the national research centres in Jülich and Karlsruhe and supported by the Max Planck Society and the German Research Foundation it will intensify relations with the People's Republic of China. The Science and Technology Office in Shanghai is expected to identify R&T-oriented, industry-related areas of cooperation that are in the mutual interest of both the People's Republic of China and Germany, organise intensive contacts between industry, science and politics in both countries and gather information required to achieve these objectives (cf. Part V, Section 2.1.4).

Cooperation with Central and Eastern European countries and with the Commonwealth of Independent States is characterised by a Federal Government programme adopted in 1992 which aims to support these states in their transition to democracy and market economy. The objective of cooperation is to contribute to stabilising economic and social development and maintain the partners' cooperativeness. In view of the long-standing cooperative relations between researchers from Germany's new Länder and research institutions and higher education institutions in the successor states of the Soviet Union and in Central and Eastern European countries, Germany is in a perfect position to act as a bridge between East and West in Europe. It is equally important to help tap the – in parts – quite considerable scientific and technical potential of these countries for cooperation with German businesses. In recent years numerous transnational cooperations were initiated or intensified under various programmes. Here -as well as under other programmes – cooperation with the neighbour countries is a natural priority.

Science and research are indispensable for independent economic and social progress in the developing countries as well. The countries of the South need their own research in order to contribute to their development themselves and participate – for their own benefit – in the process of international scientific communication. Furthermore, academically trained specialists and managers guarantee that a country can draw up and implement its own national development concepts. The Federal Ministry for Economic Cooperation supports university and non-university research in developing countries with about DM 30 million per year, appropriating the funds for measures that are specifically tailored to those countries' needs. Such measures include research cooperation between universities whose results can be used to remove obstacles to development. Young scientists receive grants and scholarships for their research projects. One research priority is postgraduate training, either at the universities in the developing countries themselves or in practice-oriented postgraduate courses held in Germany (cf. Part V, Section 2.1.5).

Part II

Resources for science, research and development in the Federal Republic of Germany and in international comparison

Contents

Introduction

Quantitative indicators have turned out to be useful instruments for providing a basis for research policy decisions and assessing the scientific and technical performance of countries and regions: Science and technology indicators are gaining in importance in view of the frequently discussed development towards a society and industry characterised by science and technology. It is of special benefit to use a large number of combined indicators in order to compensate for the limited information that individual indicators may provide. It is in particular reliability, the comparability of data on the time axis as well as the international comparability of data which are of interest to research policy.

The agreements resulting from the work of the Organisation for Economic Cooperation and Development (OECD) in particular – such as the Frascati Manual[1]) – as well as the more sophisticated tools developed in recent years in a cooperative effort by the OECD, Eurostat and the member states helped improve the methodological validation of the data and update them, e.g. in the area of innovation surveys.

This report deals both with traditional statistics of R&D expenditure (input statistics) which basically relate to financial and human resources, and with less well evolved statistics which are linked to results (output or impact statistics) and designed to provide information on the efficiency of research and research policy.

The Federal Republic of Germany participates in the further development of methodology related to science and technology indicators. Improved tools of research statistics permit extended and detailed reporting on research and will thus contribute to objective information and debate on science, research and innovation.

1. Expenditure on science

In 1993, the last year for which actual figures are available for all sectors, the expenditure of the Federal Republic of Germany on science reached a level of DM 101.4 billion. This is a rise of 1.4 % over 1992 (DM 99.9 billion), and compared with 1981 (DM 49.7 billion, related to former West Germany) the figure has even more than doubled.

According to current budgets and estimates science expenditure reached about DM 106.1 billion in 1995; this equals a rise of 3.2 % over 1994 (DM 102.8 billion).

The shares of gross national product (GNP) devoted to science expenditure in 1994 and 1995 amounted to 3.1 % in each year. In 1993 – as in 1981 – this ratio had been 3.2 %, after 3.5 % of GDP had been devoted to science in 1989.

Science expenditure comprises not only funds for research and experimental development, but also resources for scientific education and training as well as for other related scientific and technological activities.

It is important to note that – as in the previous Report – the concept of science expenditure by the Länder whose resources earmarked for science are mostly channelled to the higher education sector relies on basic funds, with direct Länder revenues (especially revenues from patient care in hospitals) being subtracted from science expenditure[2]) in order to eliminate the highly distorting impact of expenditure on patient care in university hospitals.

The contribution by public authorities to financing total science expenditure in 1993 amounted to 50.4 % (actual), that of the business enterprise sector was 48.0 %. In 1994 and 1995 the contribution by public authorities continued to rise (finally reaching 51.8 %), while that of industry dropped (to 46.7 %). In 1989 (former West Germany) the business enterprise sector had contributed 52.7 %, the public authorities 47.3 %.

While in 1995 the Federal Government's share, at 19.5 %, was slightly lower than in 1989 (20.6 %), the share of the Länder rose substantially which is mainly the result of German unification (in 1995 Germany's new Länder (excluding East Berlin) contributed about 17.2 % to the Länder governments' total science expenditure). The relatively clear positive trend of the public authorities' total science expenditure in recent years and the simultaneous stagnation of business enterprise expenditure led to a situation where the financing structure of 1995 science expenditure was very similar to that of 1981.

The Federal Government's science expenditure is mainly channelled to the non-university sector, while the better part of the Länder basic funds earmarked for science benefits the higher education sector. It was in particular in connection with financing the Special University Programmes and building up the higher education system in the new Länder that the share of the Federal Government's science funds which was allocated to higher education continued to increase in recent years (cf. Section 4). A detailed description of the flow of funds and the interlinkages between the various sectors is provided in the following sections.

[1]) Frascati Manual 1993 – Proposed Standard Practice for Surveys of Research and Experimental Development, Paris (OECD), 1994.

[2]) Net expenditure.

Table II/1

Science expenditure of the Federal Republic of Germany by financing source*)

– in % –

	1981	1989	1991	1992	1993	1994	1995
1. Government	54.8	47.3	48.5	49.7	50.4	51.0	51.8
1.1 Federal Government (including ERP)	23.8	20.6	20.9	20.8	20.1	19.4	19.5
1.2 Länder and local governments[1])	30.1	24.8	27.6	28.9	30.2	31.6	32.3
of which new Länder (without East Berlin)	–	–	*3.5*	*3.6*	*4.4*	*5.1*	*5.5*
1.3 Private Non-Profit organisations	0.9	2.0	1.8	1.7	1.6	1.6	1.5
2. Business enterprise sector	45.2	52.7	49.8	48.6	48.0	47.4	46.7
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DM million	49,741	79,375	95,703	99,924	101,353	102,836	106,094

*) Up to and including 1990 former West Germany. from 1991 onwards Germany as a whole.
[1]) Science expenditure by the Länder is not based on net expenditure, but on "basic funds" which result after deduction of direct receipts (especially Länder revenues from patient care in university hospitals).

Source: BMBF

Rounding error

2. Expenditure on research and development

In 1993, the last year for which actual data are available for all sectors, expenditure on research and development (R&D) in Germany amounted to DM 78.7 billion. This is 0.3 % up on 1992 (DM 78.5 billion).

With R&D expenditure estimated to amount to DM 79.0 billion in 1994, that year's increase in R&D expenditure of 0.5 % should be only marginally higher than that in 1993. It is estimated that in 1995 R&D expenditure rose by 2.5 % to DM 81.0 billion.

The financing structure of R&D expenditure has changed in recent years as a result of shifts in the contributions made by the individual sectors. In the 1980s a relatively dynamic growth of expenditure by the business enterprise sector compared with a rather moderate increase in contributions made by the Federal and Länder governments. The contribution to funding made by the business enterprise sector rose from 55.9 % to 63.7 %, while the shares of the Federal and Länder governments dropped from 43.7 % to 35.8 %. In the years up to and including 1995 the business enterprise sector's share shrank again to 60.3 % and those of the Federal and Länder governments picked up to 39.4 %. One decisive factor was the trend in industry to cut R&D expenditure which, after German unification, was also fed by the decline of the business enterprise sector in the new Länder. Another contributing factor was that the Federal and Länder governments substantially topped up the funds allocated to building a pan-German research system. While federal spending on R&D is now stagnating (it accounted for 20.8 % in 1995 and 22.1 % in 1991), the Länder still have an increase (the latest figure being 5.0 %) so that their contribution in 1995 was estimated at 18.6 %.

Current estimates for the business enterprise sector show a clear increase (+1.7 %) in 1995 over previous years. The contribution made by this sector has now reached a level of 60.3 % (cf. Table II/2).

The above description is based on R&D expenditure by financing sectors (backed up by the surveys conducted there)[3]). Another approach is based on R&D expenditure by performing sectors, i.e. "gross domestic expenditure on R&D". It is the approach usually underlying international comparisons (e.g. the OECD surveys; cf. Section 10). Due to the specific surveying techniques applied the level and structure of R&D expenditure differ in the two concepts. The reasons are mainly to be found in statistical methodology and technique. The most important difference is that R&D expenditure of Germany's financing sectors includes not only funds allocated to domestic sectors (higher education, non-university institutions, business enterprise sector), but also resources channelled abroad (in 1995 about DM 3.0 billion; cf. Table II/3).

Gross domestic expenditure on R&D (GERD), on the other hand, only comprises funds spent on performing R&D in Germany, i.e. R&D expenditure by domestic sectors (higher education sector, government and private non-profit sector, business enterprise sector) irrespective of financing source. In addition to funds from domestic sources (e.g. Federal and Länder governments, business enterprise sector) it also covers foreign resources which in 1993 amounted to about

[3]) In contrast to the previous concept (1993 Report of the Federal Government on Research) foreign countries are no longer included in these considerations. It is estimated that in 1995 the "Abroad" sector allocated DM 1.4 billion to financing R&D in Germany.

Table II/2

R&D expenditure of the Federal Republic of Germany*) by financing sector and in % of GNP[1])

Financing sectors[2])	1981	1989	1991	1992	1993	1994	1995
I. Federal Government[3]) – DM million ...	10,363	13,956	16,926	17,339	16,860	16,348	16,820
Index 1991 = 100	(61)	(83)	100	102	100	97	99
% of total R&D expenditure	*26.2*	*21.6*	*22.1*	*22.1*	*21.4*	*20.7*	*20.8*
II. Länder[3]) – DM million	6,898	9,157	12,287	12,888	13,546	14,340	15,060
Index 1991 = 100	(56)	(75)	100	105	110	117	123
% of total R&D expenditure	*17.5*	*14.2*	*16.0*	*16.4*	*17.2*	*18.1*	*18.6*
III. Business enterprise sector[4]) – DM million	22,082	41,197	46,998	47,945	48,023	48,090	48,900
Index 1991 = 100	(47)	(88)	100	102	102	102	104
% of total R&D expenditure	*55.9*	*63.7*	*61.4*	*61.1*	*61.0*	*60.8*	*60.3*
IV. Private non-profit sector – DM million .	155	325	380	285	241	260	260
Index 1991 = 100	(41)	(86)	100	75	63	68	68
% of total R&D expenditure	*0.4*	*0.5*	*0.5*	*0.4*	*0.3*	*0.3*	*0.3*
Total R&D expenditure – DM million ...	39,498	64,635	76,591	78,457	78,670	79,038	81,040
Index 1991 = 100	(52)	(84)	100	102	103	103	106
% of GNP[1])	*2.57*	*2.87*	*2.66*	*2.54*	*2.49*	*2.39*	*2.35*

*) Data from surveys conducted in domestic financing sectors. Up to and including 1989 former West Germany, from 1991 onwards Germany as a whole.
[1]) GNP: gross national product.
[2]) Estimated in some cases, actual figures for Federal Government up to and including 1994, for other sectors up to and including 1993. Federal Government revised from 1991 onwards.
[3]) Federal institutions (from 1981 onwards) and Länder institutions (from 1985 onwards) included only with their R&D shares.
[4]) Based on surveys conducted by SV-Wissenschaftsstatistik GmbH: R&D expenditure of all sectors (including abroad) financed by the business enterprise sector.
Source: BMBF

Rounding error

DM 1.3 billion and are likely to reach DM 1.4 billion in 1995[4]).

In 1993, the last year for which adjusted actual data are available, gross domestic expenditure on R&D (GERD) reached about DM 76.7 billion. It was thus 3.0 % higher than in 1991. The estimate for 1995 is DM 78.8 billion which is 2.7 % up on 1993.

Since the late 1980s shares in GERD of the various performing sectors have changed more or less along the lines of the shifts in R&D expenditure by financing sectors. In recent years the higher education share which in 1989 was only 14.4 % rose from 16.3 % (1991) to 18.0 % (1993). According to current estimates it reached 18.9 % in 1995. The share of the non-university sector (which includes public institutions performing research functions as well as private non-profit organisations) also grew in the period under review. While it was 13.4 % in 1989, it edged up to 14.3 % in 1991 and 15.2 % in 1993 and is estimated to slow to 15.0 % in 1995 (cf. Table II/3).

The business enterprise sector is still the dominating performing sector. This was particularly striking in 1989 (72.2 %), whereas in recent years stagnating R&D expenditure contributed towards a clear decline in industry's share (1991: 69.3 %; 1993: 66.8 %). In 1995 it should reach an estimated 66.1 %.

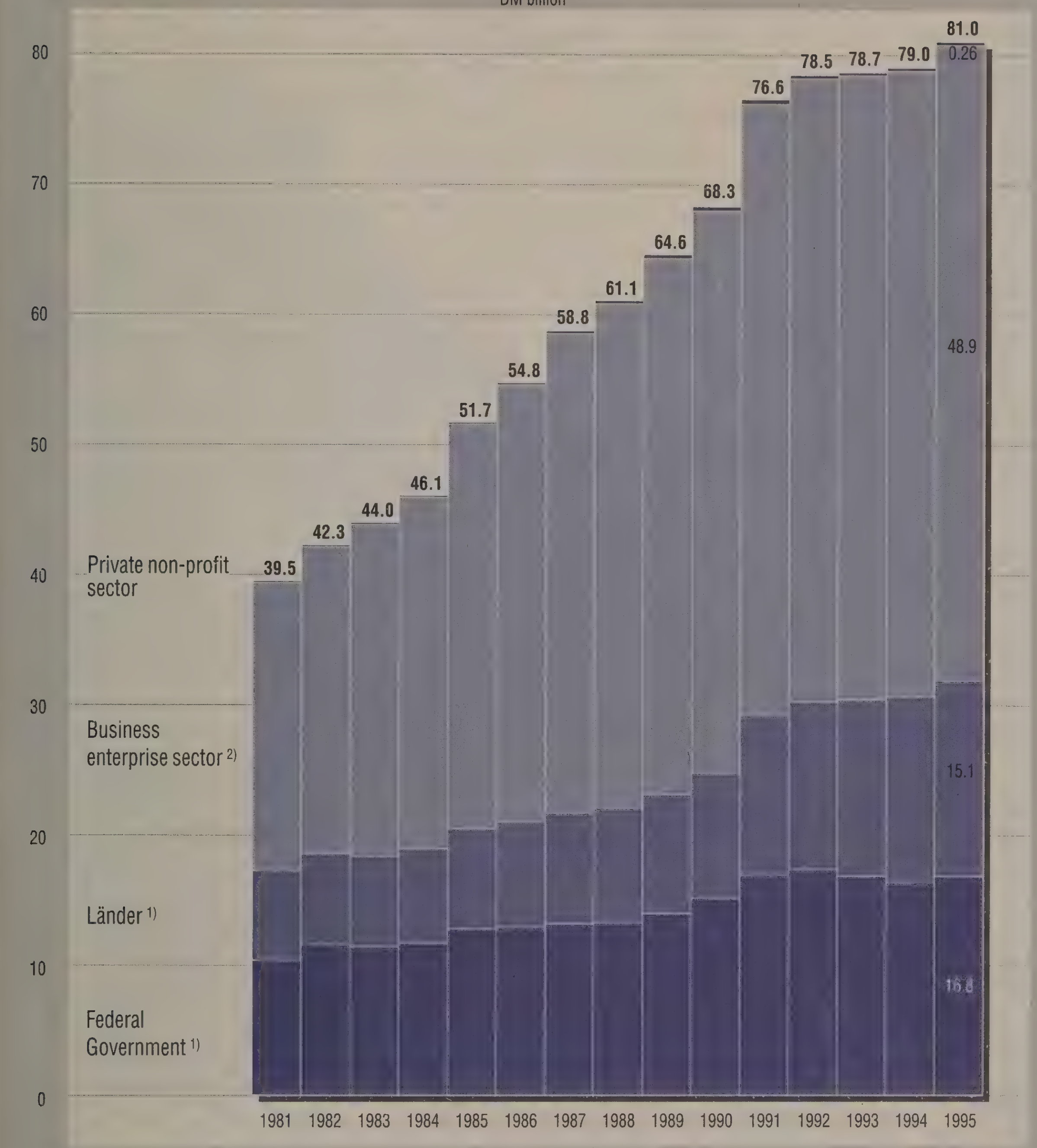
Two factors play a decisive role in the development of structural changes: First, stagnation or decline of intramural business enterprise expenditure on R&D – intensified after German unification by the reduction in R&D resources in the business enterprise sector of the new Länder – and second, the process of developing and restructuring the non-university and higher education sectors which was pushed by the Federal and Länder governments that substantially stepped up the resources allocated to these sectors.

[4]) Another example of the difference betweeen the two aggregates is the survey data relating to government funds appropriated for the business enterprise sector; here the data collected by the government tend to be higher than those provided by industry.
The different survey designs and the estimates that need to be made in some cases as well as time factors etc. influence the outcome; however, there are also methodological factors such as appraising the definition of R&D and other activities. Another crucial point is that according to international practice (Frascati Manual) indirect research funding (e.g. federal funds earmarked under the "Funding of additional R&D personnel" scheme, etc.) falls into the category of business enterprise sector and not of government funds.

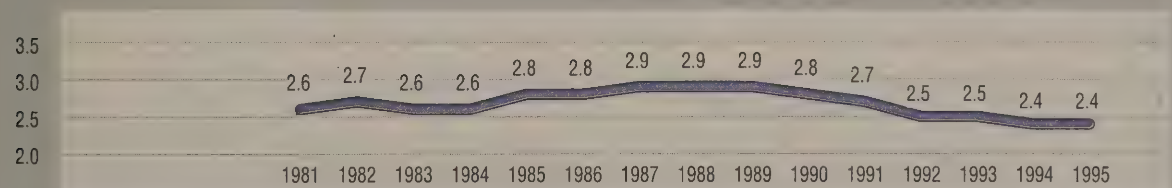
Figure II/1

R&D expenditure of the Federal Republic of Germany* by financing sector

DM billion



in % of gross national product



* Data from surveys conducted in domestic financing sectors. Up to and including 1990 former West Germany, from 1991 onwards Germany as a whole. Estimated in some cases, actual figures for Federal Government up to and including 1994, for other sectors up to and including 1993. Federal government revised from 1991 onwards.

1) Federal institutions (from 1981 onwards) and Länder institutions (from 1985 onwards) included only with their R&D shares.

2) Based on surveys conducted by SV-Wissenschaftsstatistik GmbH: R&D expenditure of all sectors (including abroad) financed by the business enterprise sector.

Source: BMBF

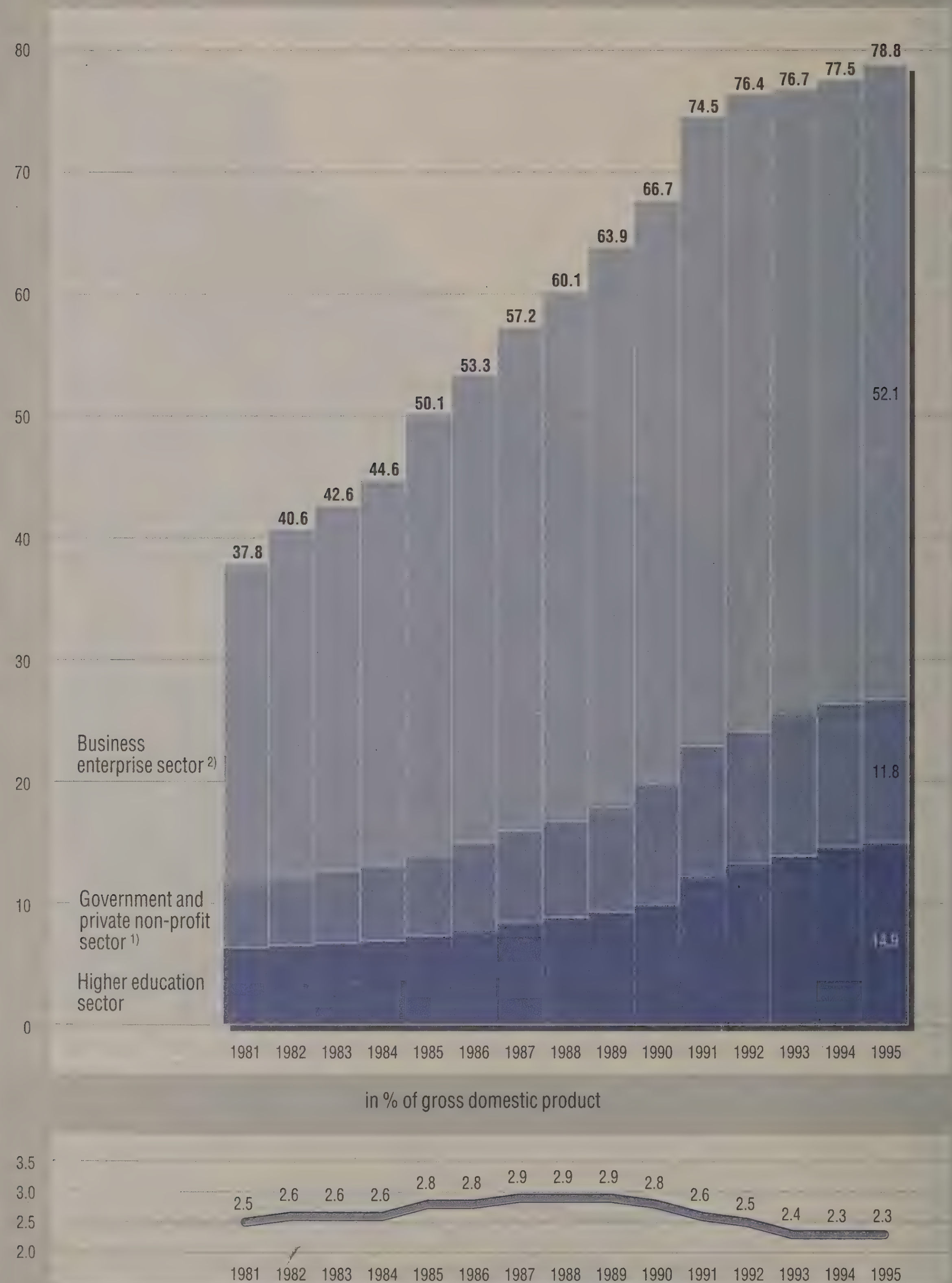
BMBF, BuFo '96

Figure II/2

Gross domestic expenditure on R&D (GERD) in Germany*

by performing sector

DM billion



* Data from surveys conducted in performing sectors. Up to and including 1990 former West Germany, from 1991 onwards Germany as a whole. Estimated in some cases, actual figures up to and including 1993, estimates from 1994 onwards. Higher education data for 1981 revised.

1) Government: (Research) institutions owned by Federal, Länder and local governments. Federal institutions from 1981 onwards, Länder institutions from 1985 onwards included only with their R&D shares. From 1992 onwards new surveying concept in government and private non-profit sector.

2) Intramural business enterprise expenditure on R&D including government funds that cannot be broken down, but excluding government funds not accounted for (OECD concept), hence deviations from financing sector data for government funds.

Source: SV-Wissenschaftsstatistik GmbH, Federal Statistical Office and BMBF calculations

BMBF, BuFo '96

The changed shares in the research budget also point to, and provide information on, the different phases of the ongoing development of the German research system (Table II/3).

Business enterprise expenditure on R&D which has risen more strongly recently (+1.8 %) – 1995 compared with 1994 – led to a slight increase in the business enterprise share over 1994. Due to stronger growth in higher education expenditure (+2.5 %), however, there was no visible change (cf. Section 8).

When gross domestic expenditure on R&D is broken down by region, the new Länder including East Berlin hold a total share of about 8.2 %, calculated on the basis of funds that can be broken down completely.

In this breakdown the non-university sector is holding the highest (17.9 %), the business enterprise sector the lowest share (4.1 %), while that of the higher education sector is 15.1 %.

The financing structure of gross domestic expenditure on R&D is also of interest (in %, 1995 estimate):

	1991	1993	1995
GERD	100.0	100.0	100.0
financed by			
Business enterprise sector	61.7	61.4	60.8
Government	35.8	36.7	7.1
Abroad	1.9	1.6	1.8

The "self-financing ratio of industry", a ratio characteristic of the business enterprise sector, has also been affected by the changes described: In 1993 the proportion of R&D performed in the business enter-

Table II/3

Gross domestic expenditure on research and development (GERD) in Germany*) by performing sector and in % of GDP[1])

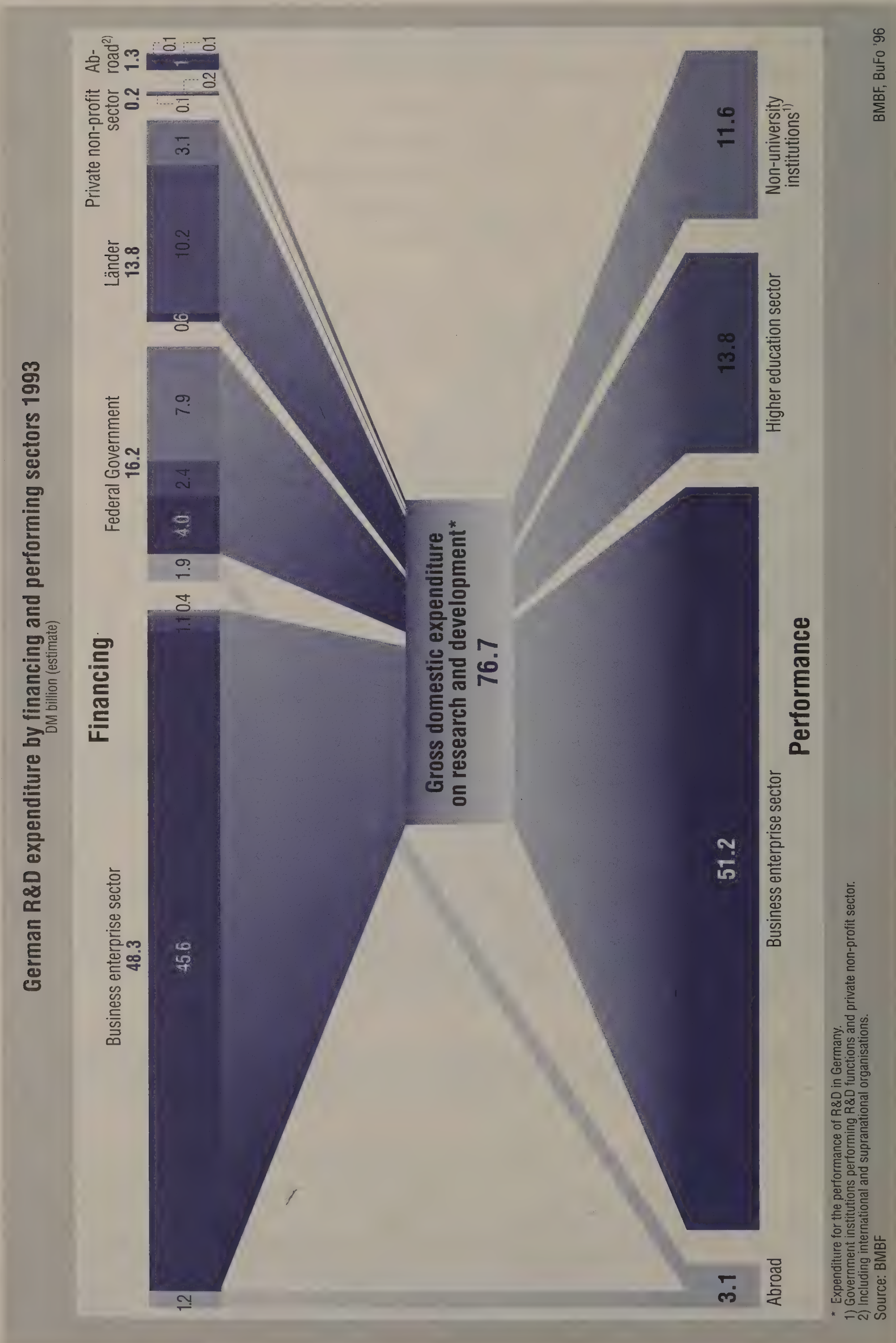
Performing sectors[2])	1981	1989	1991	1992	1993	1994	1995
I. Higher education sector – DM million	6,312	9,227	12,169	13,164	13,838	14,530	14,900
Index 1991 = 100	(52)	(76)	100	108	114	119	122
% of GERD	*16.7*	*14.4*	*16.3*	*17.2*	*18.0*	*18.7*	*18.9*
II. Government and private non-profit sector[3]) – DM million	5,304	8,559	10,673	10,906	11,647	11,800	11,800
Index 1991 = 100	(50)	(80)	100	102	109	111	111
% of GERD	*14.0*	*13.4*	*14.3*	*14.3*	*15.2*	*15.2*	*15.0*
III. Business enterprise sector[4]) – DM million	26,196	46,086	51,675	52,285	51,236	51,190	52,120
Index 1991 = 100	(51)	(89)	100	101	99	99	101
% of GERD	*69.3*	*72.2*	*69.3*	*68.5*	*66.8*	*66.0*	*66.1*
Total gross domestic expenditure on R&D (GERD) – DM million	37,812	63,872	74,517	76,355	76,721	77,520	78,820
Index 1991 = 100	(51)	(86)	100	103	103	104	106
% of GDP	*2.46*	*2.87*	*2.61*	*2.48*	*2.43*	*2.33*	*2.28*
For information:							
R&D expenditure by the Federal Government and the business enterprise sector[5]) – DM million	1,066	2,207	2,741	3,097	3,138	3,056	3,130
Index 1991 = 100	(39)	(81)	100	113	115	112	114

*) Data from surveys conducted in performing sectors. Up to and including 1989 former West Germany, from 1991 onwards Germany as a whole.
[1]) GDP: gross domestic product.
[2]) Estimated in some cases, actual figures up to and including 1993, estimates from 1994 onwards. Higher education data for 1981 revised.
[3]) Government: (Research) institutions owned by Federal, Länder and local governments. Federal institutions from 1981 onwards, Länder institutions from 1985 onwards included only with their R&D shares. From 1992 onwards new surveying concept in government and private non-profit sector.
[4]) Intramural business enterprise expenditure on R&D including government funds that cannot be broken down, but excluding government funds not accounted for (OECD concept), hence deviations from financing sector data for government funds.
[5]) Estimated in some cases.

Source: SV-Wissenschaftsstatistik GmbH, Federal Statistical Office and BMBF

Rounding error

Figure II/3


German R&D expenditure by financing and performing sectors 1993
DM billion (estimate)
Financing
Business enterprise sector
48.3
45.6
1.2
1.1
0.4
Federal Government
16.2
1.9
4.0
2.4
7.9
Länder
13.8
0.6
10.2
3.1
Private non-profit sector
0.2
0.1
0.1
Ab-road[2)]
1.3
0.1
1
0.2
0.1
Gross domestic expenditure on research and development*
76.7
Performance
Abroad
3.1
Business enterprise sector
51.2
Higher education sector
13.8
Non-university institutions[1)]
11.6
* Expenditure for the performance of R&D in Germany.
1) Government institutions performing R&D functions and private non-profit sector.
2) Including international and supranational organisations.
Source: BMBF
BMBF, BuFo '96

prise sector and financed by that sector itself was 89.0 % and thus clearly higher than in 1991 (87.1 %). The 1995 ratio is estimated to amount to 88.7 %[5]).

When R&D performed by domestic sectors (GERD) is expressed as a percentage of gross domestic product (GDP: the total value of goods and services produced in Germany) it becomes apparent that this ratio, too, has dropped considerably over the last few years. While it was still 2.87 % in 1989, it fell over the years to 2.61 % in 1991 and 2.43 % in 1993; in 1994 it was estimated at 2.33 %. It is likely to have shrunk to 2.28 % in 1995 despite an increase in R&D expenditure that was higher than in previous years (cf. Table II/3).

3. Personnel in research and development

As well as the financial resources for research and development the personnel engaged in R&D – usually, and hence also in the following, expressed as full-time equivalent, FTE – constitutes a second classic indicator for characterising the structure and development of a country's research capacities (cf. Figure II/4).

In 1993, the last year for which final data are available for all sectors, a total of 475,016 persons were working in R&D in Germany. Of these, 229,837 or 48.4 % were researchers and 245,176 or 51.6 % were technicians and other supporting staff. Compared with 1991 (516,331) the R&D personnel dropped by a total of 41,315, that is 8.0 %. At 5.0 %, shrinkage of the group of researchers was rather moderate in comparison (1991: 241,869; 1993: 229,837), while the number of technicians and other supporting staff among R&D personnel dwindled disproportionately. The percentage of researchers in total R&D personnel thus rose from 46.8 % (1991) to 48.4 %.

The decline in total research personnel in Germany over the period under review was primarily the result of changes in the new Länder where the estimate for 1991 was 34,922 persons working in the business enterprise sector, 19,509 in the higher education sector and 28,400 in the government sector, adding up to a total of 82,831.

Based on these estimates and the data collected for 1993 in the regular surveys the drop in total R&D personnel in the new Länder in the period under review was 38.3 % (31,690).

The decline in R&D personnel registered in the old Länder during those years was moderate in comparison: With a total of 423,875 in 1993 only 9,625 fewer persons were employed in the R&D sector than in 1991 (433,500) which equals a fall by 2.2 %.

In keeping with the high contribution made by the business enterprise sector to financial R&D resources the largest percentage by far of total R&D personnel is working in the this sector as well. In 1991 this percentage was 62.3 %. Due to the above-average decline of 8.7 % in this sector, it fell to 61.8 % in 1993.

The groups comprised in the category of R&D personnel were differently affected by this development: The rate of change in the group of researchers equals that of total R&D personnel; sub-average drops were identified for technicians with –5.2 % and above-average falls for other supporting staff with –12.0 %.

Again it is true that the decline in the number of R&D personnel is primarily due to a corresponding overall development in the new Länder where in the wake of unification financial and human R&D resources were reduced substantially. The data available suggest that this process is likely to have been stopped by now. After a fall of nearly 35 % in 1992 compared with 1991 the decrease in 1993 was only 3.6 % (1992: 22,864 full-time equivalent; 1993: 22,032 full-time equivalent). In the period under review the share of business enterprise R&D staff in total R&D personnel in the new Länder rose from 42.2 % (1991) to 43.1 % (1993).

Compared with all changes affecting research personnel in the old Länder the decline in industrial R&D personnel of 5.3 % is above average. In 1993 the number was 271,742, that is 15,092 fewer than in 1991.

In 1993 23.2 % of all R&D personnel in Germany worked in the *higher education sector,* compared with 20.1 % in 1991. This is equivalent to 110,020 people (full-time equivalent) in 1993, 6,156 more than in 1991. The change affecting the group of researchers (+8.0 %) was clearly greater than the above figure so that the high share of researchers in total R&D personnel in the higher education sector increased even further and reached a level of 61.0 % in 1993 (1991: 59.9 %).

The increase in research personnel in the higher education sector was 10.7 %, that is about 9,000 people (full-time equivalent) more in 1993 than in 1991. In the new Länder, however, the figure dropped by 2,829 or 14.5 %.

In 1993 the *government sector* (publicly funded research institutions and private non-profit institutions) accounted for 15.0 % (or 71,224 persons, full time equivalent) of research personnel, compared with 17.6 % in 1991. Again this decline is mostly attributable to the development in the new Länder. It should be noted that the figure estimated for 1991 includes the R&D personnel of the research institutions of the former Academies which received transitional funding and were dissolved on 31 December 1991.

In the old Länder in 1993 the percentage dropped by 5.6 % below the 1991 level. The rate of change in this sector hence more or less equals that of the business enterprise sector.

[5]) In this context the level of government funds not identified in industry surveys is of importance.

Total personnel of science institutions financed jointly by the Federal and Länder governments or by the Federal Government alone

Regional breakdown

A special survey was conducted to gain information on the regional breakdown of total personnel (personnel holding scheduled positions, additional staff and personnel financed by external funds) employed by research institutions which, pursuant to Article 91 b of the Basic Law, are jointly financed by the Federal and Länder governments, i.e. the institutes of the Max Planck Society (MPG) and the Fraunhofer Society (FhG), national research centres and institutions included in the Blue List as well as federal science institutions performing research functions. The survey thus covers the better part of the non-university sector. Not included were the Länder research institutions and private research institutions receiving the greater part of their resources neither from the business enterprise sector nor from the government; but their share in total personnel in the non-university sector is rather small, anyway.

Shares accounted for by research activities were not determined; this means that, with a few exceptions, all institutions were covered 100 %. As a result the data relating to federal institutions performing R&D functions in addition to other work are clearly higher than the data on R&D personnel collected elsewhere.

The breakdown of total R&D personnel by Länder derived from these data is shown in Table II/S.

According to this special survey, total human resources of domestic science institutions financed jointly by the Federal and Länder governments or by the Federal Government alone were just under 75,000 full-time equivalent in 1994. Based on the number of budgeted positions and the estimates made by the institutions concerned of additional staff and externally funded personnel, the number for 1995, at 77,500, was calculated to be higher by about 2,700.

Almost one fifth of the total personnel of the institutions under consideration (actual 1994) was based in Berlin, with East Berlin accounting for about one-third with approximately 5,000 persons in 1994 and 5,500 in 1995). Almost equivalent percentages of 15 % each worked in Baden-Württemberg and North Rhine-Westphalia, followed by Bavaria and Lower Saxony where about 10 % of the total personnel working in the non-university R&D sector was based. In the new Länder including East Berlin a total of about 14,800 people worked in the institutions funded jointly by the Federal and Länder governments or the Federal Government alone. This implies that the share of 20 % accounted for by these new Länder was almost the same as that of Berlin.

Table II/S

Regional breakdown of total personnel in scientific institutions funded jointly by Federal and Länder governments or financed by the Federal Government alone[1])

Land	1994 – actual –					1995 – budgeted/estimated –				
	Total	%	of which			Total	%	of which		
			scheduled positions[2])	additional personnel[3])	externally financed staff[4])			scheduled positions[2])	additional personnel[3])	externally financed staff[4])
Baden-Württemberg	**11,534**	*15.4*	7,460	2,136	1,938	**11,966**	*15.4*	7,553	2,496	1,917
Bavaria[5])	**7,823**	*10.5*	5,480	971	1,371	**8,019**	*10.3*	5,559	1,117	1,343
Berlin	**14,650**	*19.6*	11,942	1,200	1,508	**15,243**	*19.7*	12,198	1,447	1,598
East Berlin	**5,026**	*(6.7)*	*4,095*	*334*	*597*	**5,472**	*(7.1)*	*4,312*	*482*	*678*
Brandenburg	**2,728**	*3.6*	2,188	199	341	**2,950**	*3.8*	2,322	307	321
Bremen	**656**	*0.9*	347	197	112	**696**	*0.9*	356	229	112
Hamburg	**3,556**	*4.8*	3,065	291	200	**3,660**	*4.7*	3,107	322	231
Hesse	**3,422**	*4.6*	2,649	473	301	**3,586**	*4.6*	2,722	522	341
Mecklenburg-West Pomerania	**1,163**	*1.6*	1,008	46	109	**1,244**	*1.6*	1,046	61	137
Lower Saxony	**7,907**	*10.6*	6,108	822	977	**8,158**	*10.5*	6,179	924	1,056
North Rhine-Westphalia	**11,475**	*15.3*	8,371	1,536	1,568	**11,805**	*15.2*	8,406	1,782	1,618
Rhineland-Palatinate	**1,178**	*1.6*	958	98	123	**1,251**	*1.6*	1,013	111	126
Saarland	**283**	*0.4*	99	92	92	**312**	*0.4*	128	97	87
Saxony	**3,407**	*4.6*	2,458	299	651	**3,499**	*4.5*	2,385	426	687
Saxony-Anhalt	**1,582**	*2.1*	1,213	158	211	**1,686**	*2.2*	1,295	153	238
chleswig-Holstein	**2,509**	*3.4*	1,753	469	287	**2,496**	*3.2*	1,719	513	265
Thuringia	**900**	*1.2*	797	54	49	**926**	*1.2*	778	56	93
All Länder	**74,773**	*100.0*	**55,895**	**9,041**	**9,838**	**77,495**	*100.0*	**56,763**	**10,561**	**10,171**
Abroad	**312**	,	238	54	20	**312**	,	225	74	13
Total	**75,085**	***100.0***	**56,133**	**9,096**	**9,858**	**77,807**	***100.0***	**56,988**	**10,635**	**10,184**

Due to conceptual changes the above table is not fully comparable with the table published in the 1993 Report of the Federal Government on Research.

[1]) The report covers the institutions of the Max Planck Society (MPG), the Fraunhofer Society (FhG), the Blue List (BLE) as well as all national research centres and federal institutions performing research functions; all institutions are 100 % included. Exceptions: Museums included in the Blue List, German Meteorological Service, Federal Radiation Protection Office, Rationalisation Board of German Industry included only with their research shares.

[2]) Civil servants, salaried employees and wage earners listed as holding (scheduled) positions (including auxiliary staff with civil servant status as well as civil servants on probation (actual figures as of 30 June); including personnel financed from the temporary personnel augmentation fund.

[3]) Personnel financed with budget funds, but not listed as holding scheduled positions (actual figures as of 30 June); full-time equivalent.

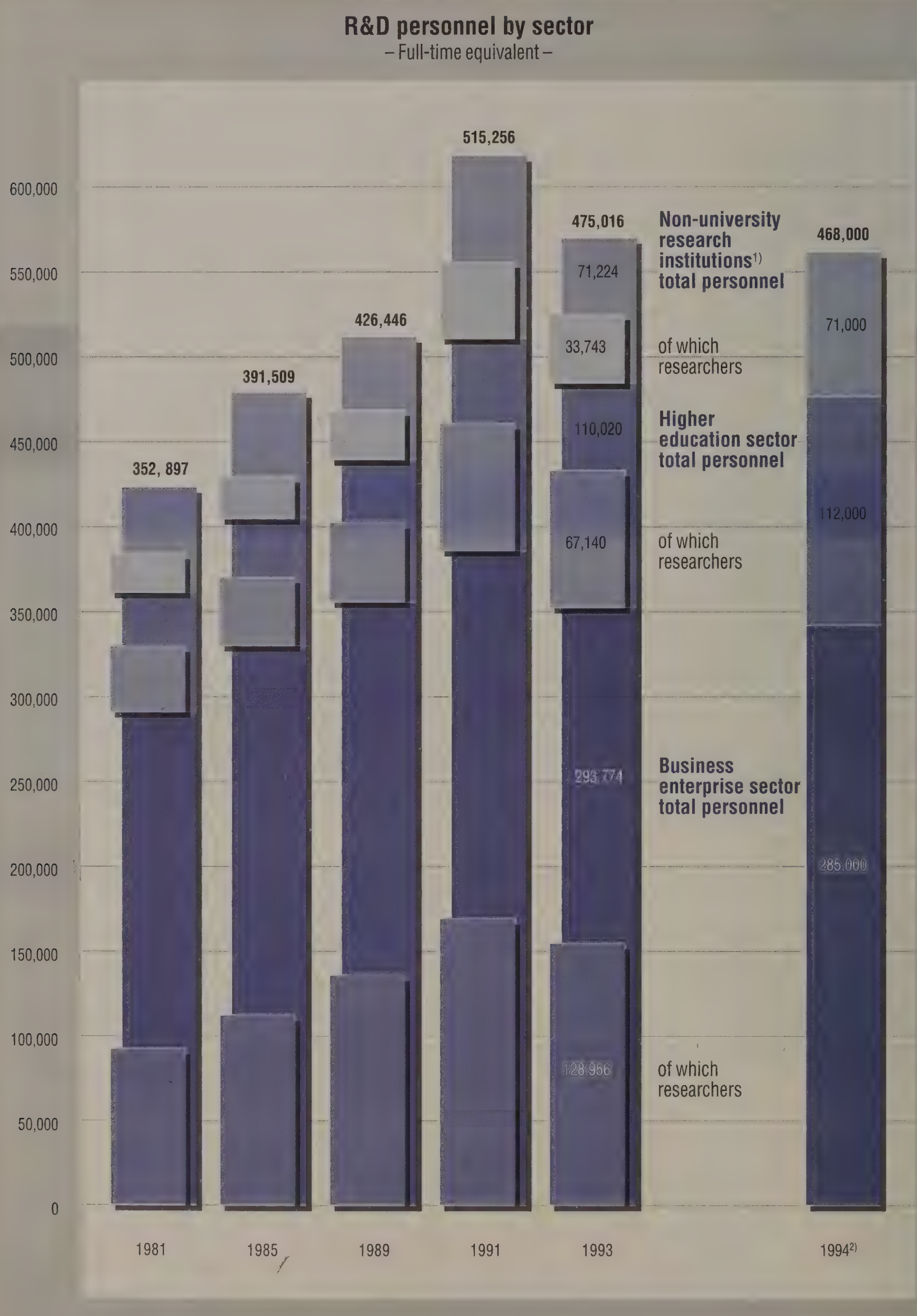
[4]) Personnel handling contract research for third parties and being paid by these (actual figures as of 30 June); full-time equivalent.

[5]) Including central administrations of MPG and FhG.

Source: BMBF

Rounding error

Figure II/4



* Up to and including 1989 former West Germany, from 1991 onwards Germany as a whole.
1) Government and private non-profit sector.
2) BMBF estimate.

Rounding error

Source: Federal Statistical Office, SV-Wissenschaftsstatistik GmbH and BMBF

BMBF, BuFo '96

4. Federal expenditure on research and development, 1981 to 1996: Development and structure

Development and financing

In 1994 the Federal Government's expenditure on research and development totalled DM 16.3 billion (actual); this was 3 % less than in the previous year. R&D expenditure budgeted for 1995 amounted to DM 16.9 billion; this equals an increase of 3.6 % over actual 1994 expenditure. The Federal Government's budget draft for 1996 appropriated DM 17.6 billion for R&D[6]).

While the budget development of only a few government departments (e.g. Federal Ministry of Defence (BMVg): –13.6 %) was a crucial determinant for R&D expenditure which in 1993 was already down on 1992, almost all federal departments contributed to the decline in expenditure registered from 1993 to 1994 (but this time the defence ministry's involvement was below average). The special development in General Fiscal Administration had only comparatively little influence.

[6]) In the period from 1981 to 1994 federal R&D expenditure rose by about 56 %, this equals an annualised 3.5 %.

The contributions made by the various government departments to financing federal R&D expenditure differ widely. In addition to the BMBF which, after the merger of the Ministry of Education and Science and the Ministry for Research and Technology, accounts for almost two-thirds of the funds, the BMVg and the Federal Ministry of Economics (BMWi) contribute major shares to federal expenditure. In 1994 the combined funds of these three ministries accounted for 88.1 % of total expenditure. R&D expenditure under departmental budget 60 (General Fiscal Administration) being excluded, the other ministries accounted for a good 10 % (cf. Table II/4 and Figure II/5). In 1994 the R&D expenditure of all ministries was lower than in 1993, with the exception of the Federal Ministry of Justice (+3.6 %). The decline in expenditure by the Federal Ministries of Transport (BMV: –0.2 %), for Family Affairs, Senior Citizens, Women and Youth (–0.5 %), for Education, Science, Research and Technology (–2.6 %) and for the Environment, Nature Conservation and Reactor Safety (BMU: nearly

Table II/4

Federal Government R&D expenditure by government department

Departmental budget	1989	1991	1992	1993	1994	1995 budget	1996 govt. draft
	actual						
	– DM million –						
Federal Ministry of Economics	988.6	1,246.8	1,198.3	1,220.9	1,155.5	1,052.8	1,008.6
Federal Ministry of Defence	3,155.5	3,192.7	3,082.3	2,662.0	2,643.3	2,898.7	3,240.0
Federal Ministry of Education, Science, Research and Technology[1])	8,446.8	9,746.1	10,597.5	10,895.2	10,607.8	11,007.6	11,321.3
General Fiscal Administration[2])	286.1	1,109.5	685.5	266.1	211.9	170.1	169.1
Other ministries	1,228.5	1,631.3	1,775.4	1,815.6	1,729.1	1,809.0	1,874.2
Total	**14,105.5**	**16,926.5**	**17,338.9**	**16,859.8**	**16,347.6**	**16,938.3**	**17,613.3**
	– in % –						
Federal Ministry of Economics	*7.0*	*7.4*	*6.9*	*7.2*	*7.1*	*6.2*	*5.7*
Federal Ministry of Defence	*22.4*	*18.9*	*17.8*	*15.8*	*16.2*	*17.1*	*18.4*
Federal Ministry of Education, Science, Research and Technology[1])	*59.9*	*57.6*	*61.1*	*64.6*	*64.9*	*65.0*	*64.3*
General Fiscal Administration[2])	*2.0*	*6.6*	*4.0*	*1.6*	*1.3*	*1.0*	*1.0*
Other ministries	*8.7*	*9.6*	*10.2*	*10.8*	*10.6*	*10.7*	*10.6*
Total	***100.0***	***100.0***	***100.0***	***100.0***	***100.0***	***100.0***	***100.0***

[1]) Up to and including 1994 expenditure by the former Ministry for Research and Technology and the former Ministry of Education and Science was combined to facilitate comparisons. Excluding total reduction of expenditure (1995: DM 100 million; 1996: DM 100 million).

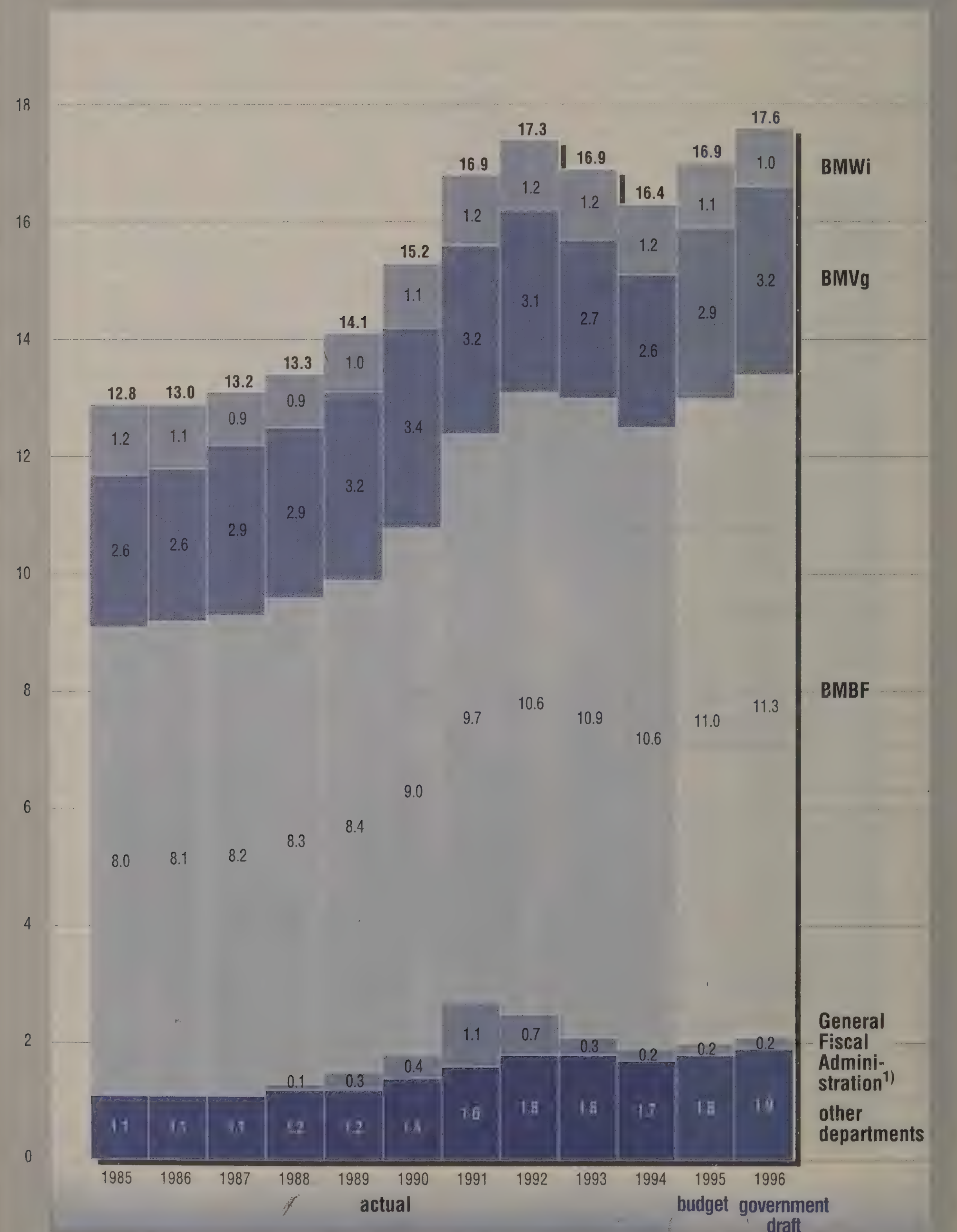
[2]) Including financial assistance to be paid pursuant to Art. 104 a para 4 of the Basic Law to Länder with a weak structure in order to invest in research and technology (1991 to 1993) and including from 1991 onwards – as a result of German unification – resources for the higher education sector and research as well as for projects conducted at industry-related research institutions.

Source: BMBF

Rounding error

Figure II/5

Federal R&D expenditure by government department, 1985 – 1996
DM billion



1) Including financial assistance to be paid pursuant to Article 104a para 4 of the Basic Law to Länder with a weak structure in order to invest in research and technology (1989 to 1992) and including from 1991 onwards – as a result of German unification – resources for higher education and research institutions and projects conducted at industry-related research institutions.

Source: BMBF

BMBF, BuFo '96

–3.0 %) was below the federal average. Judging by the 1995 and 1996 budgets substantial increases can be expected again for the majority of government departments. With +52.6 % the Federal Ministry of Labour and Social Affairs is enjoying the largest relative growth since it has been providing additional funds for testing new approaches under labour market policy. The BMV (+11.6 %), BMU (+11.1 %) and BMVg (+9.7 %) can also boast above-average increases in funds.

Thematic priorities

The Federal Government's R&D planning system permits a description of federal R&D expenditure in terms of research themes, irrespective of the financing government department. Under this system expenditure is assigned to funding areas and funding priorities; for the BMBF this is done at project level and for the other government departments at budget item level. Departing from this pattern are some separate funding priorities which are grouped to form a single funding area. Included in this grouping are basic funding of the German Research Foundation (DFG), the Max Planck Society (MPG) and the Fraunhofer Society (FhG) as well as the funds allocated to the construction of higher education institutions and to university-related special programmes and – in 1991 – transitional funding of the Academy of Sciences of the former GDR (funding priority A4). Based on the national research centres' research activities, federal basic funding of the centres is assigned to the various funding areas and priorities according to the Federal Government's R&D planning system[7]).

As in previous years the largest share (17.1 %) in federal R&D expenditure among civil funding areas in 1994 (actual) was held by "Supporting organisations; restructuring of research in the new Länder; university construction and mainly university-related special programmes". It was followed by "Space research and space technology" with 9.9 %. Third place was held by "Large-scale equipment in basic research" and "Environmental research; climate research" with 6.3 % each. "Information technology (including production engineering)" (6.0 %) and "Energy research and energy technology" (5.5 %) also held quite substantial shares in R&D expenditure. The increase in the share of "Innovation and improved basic conditions" to just under 4.7 % deserves special mention. This rise is attributable to the funds allocated to "Improving the transfer of technology and knowledge" and "Other promotion measures (BMWi)" which mostly benefited the new Länder (cf. Table II/8).

The data determined on the basis of the 1995 budget do not indicate any major changes compared with 1994 expenditure. The previously dominating funding areas will not lose their relative importance. The funds allocated to "Supporting organisations; restructuring of research in the new Länder; university construction and mainly university-related special programmes" (17.5 %) and "Innovation and improved basic conditions" (4.9 %) will be stepped up again. The shares of "Space research and space technology" (9.4 %) and "Large-scale equipment in basic research" (6.3 %), however, will shrink. This applies in particular to "Aeronautical research and hypersonic technology" whose share will fall to only 2.1 % in 1995 (budgeted). The reason for this decline is that grants for the development of civil aircraft in the BMWi's budget were cut down, while the funding programme for hypersonic technology which was phased out was more then compensated for by an increment in BMBF funds earmarked for the new aeronautical research programme.

The development between 1993 and 1994 of R&D expenditure on the individual funding areas and the associated funding priorities varied widely (cf. Table II/5). The highest relative growth was registered in the funding areas "Innovation and improved basic conditions" (+15 %) and "Geosciences and raw material supplies"(+11.4 %) as well as in the funding priority "Basic funding FhG" (+10.9). Some of the other funding areas developed along moderately positive lines, others had to put up with substantial cut-downs, e.g. "Aeronautical research and hypersonic technology" (–24.0 %), "Specialised information" (–16.8 %) as well as "Research and development in agriculture, forestry and fishery" (–11.4 %).

The target figures given in the Federal Government's budget draft for the fiscal year 1996 show that the decline in funds for the above-mentioned funding areas that occurred in 1993 and 1994 will not continue. An exception is "Aeronautical research and hypersonic technology" (–2.6 %); "Geosciences and raw material supplies" will also be affected by a cut-down in funds (–3.7 %). After substantial decreases in the years between 1990 and 1993 "Defence research and defence technology" can expect a major rise. Although there was already an increase of +9.8 % from 1994 (actual) to 1995 (budgeted), the target of the 1996 budget draft is another rise by +11.8 % (cf. Table II/5).

Looking at BMBF R&D expenditure alone in 1993 and 1994 (Table II/6) it becomes apparent that for the majority of funding areas this expenditure determined or enhanced the development of total federal expenditure. In addition to an increase in funds for "Geosciences and raw material supplies" (+24.0 %) mention should be made of the disproportionate rise in expenditure on "Innovation and improved basic conditions" (+7.5 %). Above-average relative cuts were suffered by "Specialised information" (–24.2 %), "Building research" (–20.9 %), "Energy research and energy technology" (–15.1 %), "Aeronautical research and hypersonic technology" (–12.3 %), "Oth-

[7]) Due to the merger of the Federal Ministries of Education and Science and for Research and Technology the Federal Government's R&D planning system was extended to include additional funding priorities. Funding priority A6 covers "Mainly university-related special programmes" which had previously been assigned to several other funding priorities. "Educational research" was divided into "Vocational training research" and "Other educational research". The present account which focuses on science, research and development does still not include expenditure under the Federal Training Assistance Act nor other educational expenditure that is not relevant to R&D or science.

Table II/5

Federal R&D expenditure by funding area and funding priority

– DM million –

Funding area / Funding priority		1993 actual	1994 actual	1995 budget[3])	1996 govt. draft[3])
A	**Supporting organisations; restructuring of research in the new Länder; university construction and mainly university-related special programmes**	**2,805.7**	**2,798.3**	**2,964.6**	**3,022.4**
A1	Basic funding MPG	608.6	638.0	702.1	719.5
A2	Basic funding DFG	814.1	871.3	936.0	982.8
A3	Basic funding FhG	363.4	402.9	409.9	418.1
A5	Expansion and construction of universities[1])	545.5	545.2	581.3	606.6
A6	Mainly university-related special programmes[2])	474.1	340.9	335.3	295.5
B	**Large-scale equipment for basic research**	**1,017.1**	**1,023.8**	**1,065.9**	**1,075.1**
C	**Marine research and marine technology; polar research**	**275.2**	**276.8**	**281.4**	**288.2**
C1	Marine research	139.2	149.9	152.2	154.9
C2	Marine technology	61.6	53.3	53.9	55.1
C3	Polar research	74.4	73.6	75.3	78.1
D	**Space research and space technology**	**1,803.5**	**1,622.1**	**1,593.5**	**1,598.4**
D1	National funding of space research and space technology	615.1	581.3	523.5	528.4
D2	European Space Agency (ESA)	1,188.4	1,040.8	1,070.0	1,070.0
E	**Energy research and energy technology**	**1,034.8**	**893.5**	**879.7**	**900.8**
E1	Coal and other fossil fuels	71.4	57.0	47.2	47.6
E2	Renewable energies and energy conservation	347.4	314.4	331.0	349.2
E3	Nuclear energy research (excluding decommissioning of nuclear facilities)	361.7	300.2	283.4	290.6
E4	Decommissioning of nuclear facilities; risk sharing[2])	37.2	22.1	21.6	23.3
E5	Thermonuclear fusion research	217.1	199.9	196.5	190.1
F	**Environmental research; climate research**	**1,036.3**	**1,029.5**	**1,041.3**	**1,090.1**
F1	Ecological research	446.7	435.3	426.4	450.2
F2	Environmental technologies	355.7	344.9	372.8	396.2
F7	Climate and atmospheric research	234.0	249.3	242.2	243.7
G	**Research and development in the service of health**	**764.5**	**757.8**	**781.1**	**822.6**
H	**Research and development to improve working conditions**	**102.0**	**95.8**	**97.6**	**100.9**
I	**Information technology (including production engineering)**	**960.2**	**978.5**	**1,024.7**	**1,053.0**
I1	Computer science	235.3	228.7	238.0	254.1
I2	Basic information technologies	448.2	481.2	497.6	507.0
I3	Application of microsystems (including microelectronics and microperipherals)	154.8	155.2	163.0	165.0
I4	Production engineering	121.9	113.3	126.0	127.0
K	**Biotechnology**	**388.0**	**375.3**	**426.6**	**450.0**
L	**Materials research; physical and chemical technologies**	**616.4**	**607.6**	**638.1**	**660.2**
L1	Materials research; materials for technologies of the future	272.9	252.4	270.1	275.1
L2	Physical and chemical technologies	343.6	355.1	367.9	385.1
M	**Aeronautical research and hypersonic technology**	**619.6**	**470.6**	**350.3**	**341.3**
N	**Research and technology for ground transport (including traffic safety)**	**227.2**	**219.4**	**247.8**	**248.7**
O	**Geosciences and raw material supplies**	**242.0**	**269.7**	**211.6**	**203.8**
O1	Geosciences (especially deep drillings)	207.1	237.1	185.6	177.4
O2	Raw material supplies	34.9	32.6	26.1	26.4

cont. Table II/5

	Funding area Funding priority	1993 actual	1994 actual	1995 budget[3])	1996 govt. draft[3])
P	**Regional planning and urban development; building research**	**180.7**	**168.8**	**174.6**	**176.5**
P1	Regional planning, urban development, housing	51.4	50.2	47.9	48.2
P2	Building research and technology, research and technology for preserving the architectural heritage; road building research	129.3	118.6	126.6	128.3
Q	**Research and development in the food sector**	**103.3**	**108.1**	**106.9**	**112.9**
R	**Research and development in agriculture, forestry and fishery**	**288.4**	**255.5**	**254.2**	**263.1**
S	**Educational research**	**130.5**	**128.7**	**133.3**	**142.0**
S1	**Vocational training research**	73.2	72.5	75.3	75.7
S2	**Other educational research**	57.3	56.2	58.0	66.3
T	**Innovation and improved basic conditions**	**664.8**	**764.6**	**830.1**	**870.2**
T1	Indirect funding of R&D personnel in the business enterprise sector	113.5	86.4	110.0	146.0
T2	Improving the transfer of technology and knowledge	138.6	194.2	177.3	234.0
T3	Sharing the innovation risk of technology-based firms	81.7	72.6	85.0	72.2
T4	Other indirect promotion measures (excluding indirect specific measures)	169.6	169.9	170.0	170.0
T8	Rationalisation as well as scientific and technical departmental services (Federal Ministry of Economics)	4.2	4.3	4.6	4.6
T9	Other promotion measures (Federal Ministry of Economics)	157.1	237.1	283.2	243.4
U	**Specialised information**	**76.1**	**63.3**	**56.4**	**57.8**
V	**Humanities; economic and social sciences**	**475.8**	**460.8**	**491.5**	**499.2**
W	**Other acitvities not assigned to other sectors**	**412.6**	**369.0**	**421.4**	**432.3**
A-W	**Total civil promotion areas**	**14,224.8**	**13,737.4**	**14,072.5**	**14,409.6**
X	**Defence research and technology**	**2,635.0**	**2,610.2**	**2,865.8**	**3,203.7**
Total expenditure		**16,859.8**	**16,347.6**	**16,938.3**	**17,613.3**

[1]) Including universities of the Federal Armed Forces and Federal Fachhochschule for Public Administration.
[2]) Including programme for ensuring academic efficiency and access to overcrowded courses (HSP I), programme ensuring the efficiency of universities and research and for promoting young scientists (HSP II) as well as the Programme for the Renewal of Higher Education and Research in the New Länder and East Berlin.
[3]) Estimated in some cases.

Source: BMBF

Rounding error

Table II/6

R&D expenditure of the Federal Ministry of Education, Science, Research and Technology by funding area and funding priority

– DM million –

Funding area Funding priority		1993 actual	1994 actual	1995 budget	1996 govt. draft
A	**Supporting organisations; restructuring of research in the new Länder; university construction and mainly university-related special programmes**	**2,593.7**	**2,667.4**	**2,844.6**	**2,901.3**
A1	Basic funding MPG	608.6	638.0	702.1	719.5
A2	Basic funding DFG	814.1	871.3	936.0	982.8
A3	Basic funding FhG	363.4	402.9	409.9	418.1
A5	Expansion and construction of universities	504.0	504.0	540.0	564.0
A6	Mainly university-related special programmes[1])	303.5	251.2	256.6	216.9
B	**Large-scale equipment for basic research**	**1,017.1**	**1,023.8**	**1,065.9**	**1,075.1**
C	**Marine research and marine technology; polar research**	**263.5**	**265.2**	**269.6**	**273.5**
C1	Marine research	138.9	149.6	151.9	154.6
C2	Marine technology	50.1	42.0	42.3	42.8
C3	Polar research	74.4	73.6	75.3	76.1
D	**Space research and space technology**	**1,803.5**	**1,622.1**	**1,593.4**	**1,581.8**
D1	National funding of space research and space technology	615.1	581.3	523.4	511.8
D2	European Space Agency (ESA)	1,188.4	1,040.8	1,070.0	1,070.0
E	**Energy research and energy technology**	**957.3**	**812.8**	**786.8**	**796.8**
E1	Coal and other fossil fuels	70.7	56.3	46.5	46.9
E2	Renewable energies and energy conservation	345.4	312.3	329.1	347.2
E3	Nuclear energy research (excluding decommissioning of nuclear facilities)	286.9	222.2	193.1	189.4
E4	Decommissioning of nuclear facilities; risk sharing	37.2	22.1	21.6	23.3
E5	Thermonuclear fusion research	217.1	199.9	196.5	190.1
F	**Environmental research; climate research**	**710.1**	**702.6**	**741.8**	**785.4**
F1	Ecological research	240.7	240.0	244.1	249.6
F2	Environmental technologies	257.6	242.7	292.0	331.9
F7	Climate and atmospheric research	211.9	219.9	205.7	204.0
G	**Research and development in the service of health**	**538.3**	**544.1**	**564.5**	**586.4**
H	**Research and development to improve working conditions**	**69.8**	**65.5**	**65.0**	**65.0**
I	**Information technology (including production engineering)**	**925.3**	**945.4**	**982.6**	**1,010.2**
I1	Computer science	207.1	203.9	212.1	228.7
I2	Basic information technologies	441.5	477.5	479.2	489.2
I3	Application of microsystems (including microelectronics and microperipherals)	154.8	155.2	165.3	165.4
I4	Production engineering	121.9	108.8	126.0	127.0
K	**Biotechnology**	**295.9**	**282.2**	**310.6**	**331.4**
L	**Materials research; physical and chemical technologies**	**490.3**	**478.6**	**510.9**	**534.4**
L1	Materials research; materials for technologies of the future	249.6	228.5	244.9	254.7
L2	Physical and chemical technologies	240.7	250.1	266.0	279.6
M	**Aeronautical research and hypersonic technology**	**206.5**	**181.2**	**209.5**	**250.7**
N	**Research and technology for ground transport (including traffic safety)**	**159.7**	**158.2**	**180.0**	**182.0**

cont. Table II/6

	Funding area Funding priority	1993 actual	1994 actual	1995 budget	1996 govt. draft
O	Geosciences and raw material supplies	**128.8**	**159.7**	**117.0**	**106.7**
O1	Geosciences (especially deep drillings)	127.9	159.7	117.0	106.7
O2	Raw material supplies	0.9	–	–	–
P	**Regional planning and urban development; building research**	**36.9**	**29.2**	**29.0**	**30.0**
P2	Building research and technology, research and technology for preserving the architectural heritage, road building research	36.9	29.2	29.0	30.0
S	**Educational research**	**130.5**	**128.7**	**133.3**	**142.0**
S1	Vocational training research	73.2	72.5	75.3	75.7
S2	Other educational research	57.3	56.2	58.0	66.3
T	**Innovation and improved basic conditions**	**187.4**	**201.5**	**225.0**	**276.0**
T1	Indirect funding of R&D personnel in the business enterprise sector	21.1	18.7	18.0	16.0
T2	Improving the transfer of technology and knowledge	84.7	113.7	122.0	187.8
T3	Sharing the innovation risk of technology-based firms	81.7	69.1	85.0	72.2
U	**Specialised information**	**55.8**	**42.3**	**37.5**	**37.3**
V	**Humanities; economic and social sciences**	**144.8**	**136.3**	**139.4**	**140.2**
W	**Other activities not assigned to other sectors**	**180.0**	**161.2**	**201.2**	**214.9**
	Total expenditure	**10,895.2**	**10,607.8**	**11,007.6[2])**	**11,321.3[2])**

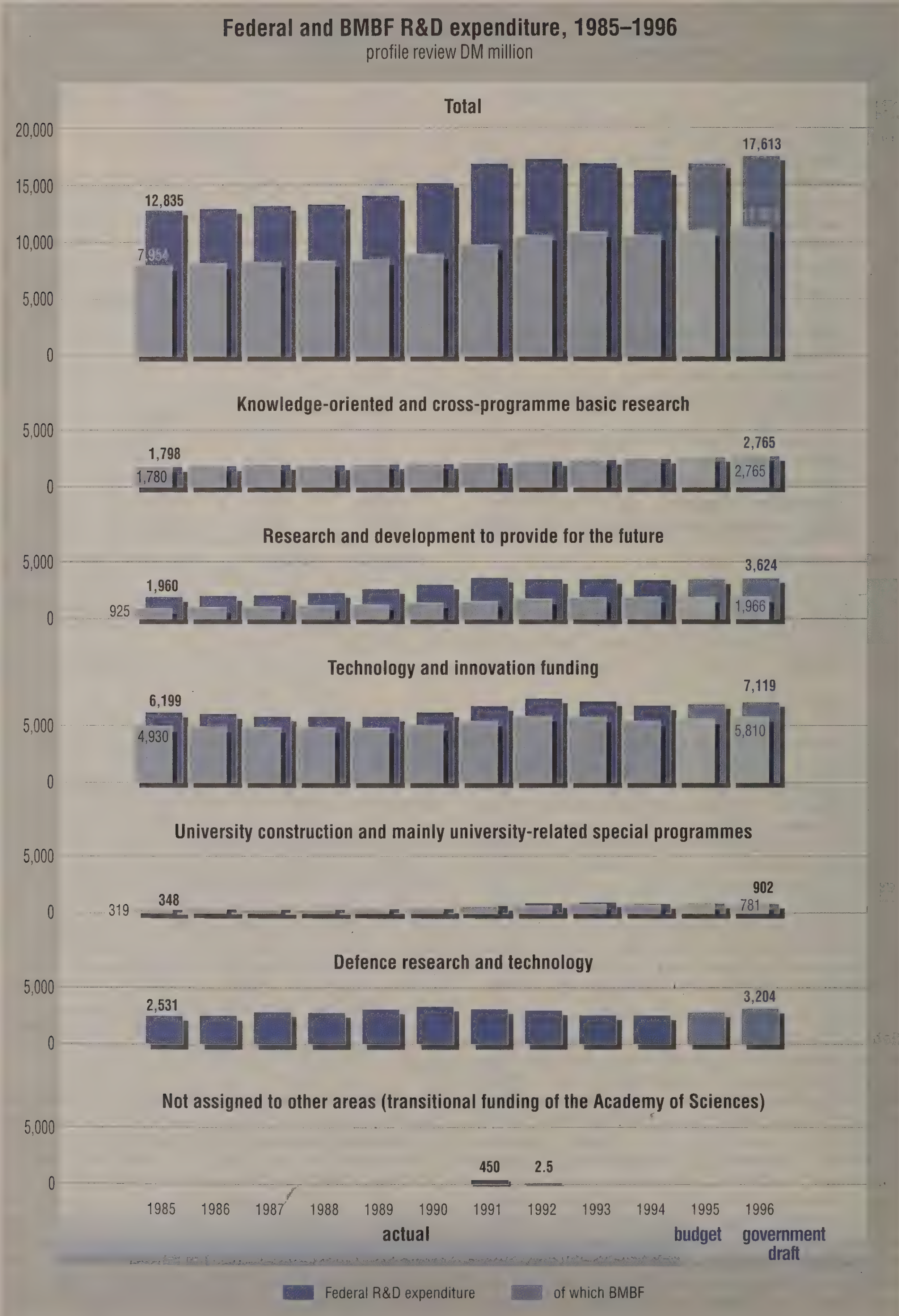
[1]) Including programme for ensuring academic efficiency and access to overcrowded courses (HSPI), programme ensuring the efficiency of universities and research and for promoting young scientists (HSPII) as well as the Programme for the Renewal of Higher Education and Research in the New Länder and East Berlin.
[2] Excluding total reduction of expenditure (1995: DM 100 million, 1996: DM 129 million).
Source: BMBF — Rounding error

er activities not assigned to other sectors" (–10.4 %) and "Space research and space technology" (–10.1 %). The relatively modest increase (+2.8 %) in expenditure on "Supporting organisations; restructuring of research in the new Länder; university construction and mainly university-related special programmes" – with high growth of basic funding of the research and research funding organisations MPG, DFG and FhG – was attributable to diminishing funds allocated to the University Renewal Programme as well as to the fact that the programme for ensuring the efficiency of universities and research and for promoting young scientists was being phased out.

Given a low starting level in some cases, the target data for 1995 indicate a relative increase that is far above average for the funds earmarked for "Other activities not assigned to other sectors" (e.g. for funding international cooperation with other countries, organisations and research institutions) (+24.8 %), "Research and technology for ground transport" (+13.8 %), "Aeronautical research and hypersonic technology" (+15.6 %), "Innovation and improved basic conditions" (+11.7 %) and "Biotechnology" (+10.1 %). Note should also be taken of the above-average increment in expenditure on "Environmental research; climate research" (+5.6 %) and "Information technology (including production engineering)" (+3.9 %). In spite of the reduced funds earmarked for university-related special programmes an above-average rate of increase (+6.6 %) is expected again for the funding area "Supporting organisations; restructuring of research in the new Länder; university construction and mainly university-related special programmes". After a substantial increase from 1993 to 1994 in expenditure on "Geosciences and raw material supplies" present budget figures indicate an equally marked relative decline in expenditure (–26.7 %). There are several causes for the substantial variations in the development of this funding area: In 1992 the Potsdam Geoscientific Research Centre was founded as a national research centre which since 1993 has received additional financial resources; the 1995 budget envisages reduced BMBF project funds for geosciences and mining technologies.

The 1996 budget data indicate major departures from the average rate of change in the funding areas "Innovation and improved basic conditions" (+22.7 %), "Aeronautical research and hypersonic technology" (+19.7 %), "Other activities not assigned to other sectors" (+6.8 %), "Biotechnology" (+6.7 %) as well as "Educational research" (+6.5 %). The repeated decline of BMBF project funds will result in a negative trend for "Geosciences and raw material supplies'. As regards the development of 1995 BMBF target data and the figures in the Federal Government's 1996

Figure II/6



Source: BMBF

BMBF, BuFo '96

budget draft it should be pointed out that they do not include the total reduction in expenditure (1995: DM 100 million; 1996: DM 129 million) since expenditure can only be definitively assigned to funding areas or priorities once the actual figures are available.

Development of the basic structure

In the "profile review" (cf. Figure II/6) the R&D expenditure on individual funding areas or priorities is grouped to form functions, thus permitting a better overview – when R&D funds are appropriated – of the trend of the basic structure of research funding in recent years as well as of the current definition of priorities. When the Ministries of Education and Science and for Research and Technology were merged the funding areas and priorities were analysed with regard to their objectives and some were assigned to other functions. The former functions "Long-term government programmes" and "Preventive research" were merged to form a new function "Research and development to provide for the future"; university construction and mainly university-related special programmes were taken out of the former function "Cross-programme basic research". As a result of reappraisal the funding area "Space research and space technology" and the funding priority "Thermonuclear fusion research" were assigned to the function "Technology and innovation research". To facilitate comparisons the funding areas and priorities affected by this new structure of the profile were transferred accordingly also for previous years.

It can be seen from Table II/7 which shows the profile structure of federal R&D expenditure from 1989 to 1996 that the share of "Promotion of technology and innovation" increased marginally from 41.4 % (1989) to 41.8 % (1994). According to the 1995 budget estimate and the 1996 draft budget this share will decline. "Research and development to provide for the future" had the second largest share; its actual percentage was 21.3 % in 1994, compared with 18.9 % in

Table II/7
(cf. Table II/5)

Federal expenditure on research and development
– profile review –

– DM million –

Function[1]) (associated funding areas and funding priorities)	1989	1991	1992	1993	1994	1995 actual	1996 govt. draft
	actual						
1. Knowledge-oriented research and cross-programme basic research (MPG, DFG, large-scale equipment for basic research) (A1, A2, B)	2,045.9	2,145.2	2,318.8	2,439.9	2,533.2	2,678.4	2,764.8
2. Research and development to provide for the future (C1, C3, F1, F7, G, H, O1, P1, P2, Q, R, S1, S2, V, W1)	2,668.9	3,656.0	3,547.2	3,559.2	3,489.6	3,534.6	3,624.1
3. Funding of technology and innovation (A3, C2, D1, D2, E1, E2, E3, E4, E5, F2, I1, I2, I3, I4, K, L1, L2, M, N, O2, T1, T2, T3, T4, T8, T9, U)	5,840.3	6,780.4	7,447.9	7,206.1	6,828.5	6,942.9	7,118.5
4. University construction and mainly university-related special programmes (A5, A6)	422.7	725.1	957.3	1,019.6	886.1	916.6	902.1
5. Defence research and technology (X)	3,127.6	3,169.8	3,065.2	2,635.0	2,610.2	2,865.8	3,203.7
8. Miscellaneous (Transitional funding of Academy of Sciences) (A4)	–	450.0	2.5	–	–	–	–
Total	**14,105.5**	**16,926.5**	**17,338.9**	**16,859.8**	**16,347.6**	**16,938.3**	**17,613.3**

[1]) Functions 6 and 7 relate to expenditure (including resources appropriated under the Federal Training Assistance Act) that ist not relevant to R&D.

Source: BMBF

Rounding error

1989. With 15.5 %, the function "Knowledge-oriented and cross-programme basic research" was one percentage point up on 1989. The newly created function "University construction and university-related special programmes" held a share of 5.4 % in 1994, compared with 3.0 % in 1989. "Defence research and technology" suffered a major decline as its share dropped from the 1989 level by almost six percentage points to 16.0 % in 1994. Despite an increase in expenditure on this function in the 1995 budget and the 1996 government draft (16.9 % and 18.2 %, respectively) its share shrank in the period from 1989 to 1996 by a total of 4 percentage points in favour of civil functions.

Table II/8 shows the BMBF R&D expenditure broken down by functions, highlighting not only the structural changes in the profile, but also the inclusion of additional funding priorities which indicates a departure from the profile review published last (by the then Federal Ministry for Research and Technology). According to the current review there were cuts between 1989 and 1994 in "Promotion of technology and innovation" (1989: 56.6 %; 1994: 51.0 %) in favour of the functions "Research and development to provide for the future" (1989: 14.8 %; 1994: 18.0 %) and "University construction and mainly university-related special programmes" (1989: 4.6 %; 1994: 7.1 %). In 1994 the share of "Knowledge-oriented and cross-programme basic research" (24.0 %) was at about the same level as in 1989 (23.9 %). According to the 1995 budget and the 1996 government draft this share will pick up while at the same time that of "Research and development to provide for the future" will decline.

Expenditure by type of funding

The breakdown of federal R&D expenditure by type of funding shows that in 1994 44.5 % of funds went into projects which was slightly less than in 1993 (44.7 %). These resources also included appropriations for indirect and indirect specific funding (excluding tax-related measures) which in the period from 1992 to 1996 focused especially on small and

Table II/8
(cf Table II/6)

Expenditure on research and development by the Federal Ministry of Education, Science, Research and Technology[1])
– profile review –

– DM million –

Function[1]) (associated funding areas and funding priorities)	1989	1991	1992	1993	1994	1995 actual	1996 govt. draft
	actual						
1. Knowledge-oriented research and cross-programme basic research (MPG, DFG, large-scale equipment for basic research) (A1, A2, B)	2,024.9	2,144.1	2,318.7	2,439.9	2,533.2	2,678.4	2,764.8
Basic research included in functions 2 to 4	*1,914.3*	*2,427.3*	*2,676.3*	.	.	.	.
Total basic research	*3,939.2*	*4,571.4*	*4,995.0*				
% of BMBF R&D expenditure	*46.6*	*46.9*	*47.1*	.	.	.	.
2. Research and development to provide for the future (C1, C3, F1, F7, G, H, O1, P2, S1, S2, V, W1	1,252.9	1,561.7	1,763.4	1,894.1	1,907.7	1,922.4	1,965.7
3. Funding of technology and innovation (A3, C2, D1, D2, E1, E2, E3, E4, E5, F2, I1, I2, I3, I4, K, L1, L2, M, N, O2, T1, T2, T3, U)	4,781.1	5,388.1	5,835.2	5,753.7	5,411.7	5,610.2	5,809.8
4. University construction and mainly university-related special programmes (A5, A6)	387.9	652.1	680.2	807.5	755.2	796.6	780.9
Total	**8,446.8**	**9,746.1**	**10,597.5**	**10,895.2**	**10,607.8**	**11,007.6[2])**	**11,321.3[2])**

[1]) Up to and including 1994 R&D expenditure by the former Ministry for Research and Technology and the former Ministry of Education and Science was combined to facilitate comparisons.
[2]) Excluding total reduction of expenditure (1995: DM 100 million, 1996: DM 129 million).
Source: BMBF

Rounding error

medium-sized enterprises in the new Länder to support local research capacities. These schemes cover technology transfer, sharing the innovation risk of technology-based companies, research cooperation between industry and science, cooperative industrial research and development as well as contract research and development both in the new and the old Länder (including research cooperation between companies and research institutions) (cf. Part II, Section 9).

In 1994 almost 41 % of federal R&D expenditure was accounted for by basic funding of institutions; this included the R&D expenditure by federal scientific institutions listed in the federal budget. The percentage of this type of funding grew (1993: 39.6 %) because resources were increased for institutions included in the "Blue List" and for institutions funding research and science (MPG, DFG, FhG). The funds allocated to national research centres dropped only marginally from 15.9 % in 1993 to 15.7 % in 1994. According to the 1995 budget and the 1996 draft the total share of basic funding of institutions in federal R&D expenditure will be just over 40 %, with funds allocated to individual institutions developing along different lines.

In 1994 the share of *international cooperation* in federal R&D expenditure fell below 10 % and is now 9.4 %. This share of 9.4 % has also been budgeted for 1995. In the 1996 draft it will presumably drop to 9.1 %.

Expenditure by recipient group

A breakdown of the Federal Government's expenditure on research and development by recipient group provides an overview of the distribution of federal funds channelled to recipients in the various sectors of the economy for performing R&D or earmarked for financing their R&D. The trend of actual expenditure from 1981 to 1994 shows that the funds for the "Business enterprise sector" dropped sharply from 42.8 % to 27.2 %, while some of the other recipient groups enjoyed sizeable increases.

In 1994 government institutions (institutions of Federal, Länder and local governments including the higher education sector) received about DM 3.5 billion which accounted for 21.2 % of federal R&D expenditure. This sum did not include funds appropriated to the German Research Foundation for the benefit of the higher education sector; in this overview these funds – due to the system applied – appear in the category of scientific non-profit organisations.

The higher education sector (including university hospitals) received the following federal R&D funds, including the resources channelled through the German Research Foundation:

1992 (actual)	DM 2.2 billion
1993 (actual)	DM 2.2 billion
1994 (actual)	DM 2.2 billion
1995 (budgeted)	DM 2.4 billion
1996 (government draft)	DM 2.5 billion

The trend observed indicates that federal funds appropriated for research in the higher education sector tend to stabilise at a high level. There are several factors which influence the volume of federal funds allocated to higher education: First of all, there are federal project funds and, above all, the Federal and Länder governments' jointly financed Special University Programmes (HSP) for ensuring academic efficiency and access to overcrowded courses (HSP I) as well as for promoting young scientists (HSP II). Furthermore, in the process of restructuring the higher

Table II/9

Federal R&D expenditure by recipient group

– in % –

Recipient group	1989	1990	1991	1992	1993	1994	1995[1]) budget	1996[1]) govt. draft
	actual							
Territorial authorities	19.8	20.2	21.5	20.7	20.5	21.2	20.6	20.5
of which:								
Federal Government-owned institutions	8.5	7.9	8.5	9.2	9.6	9.6	9.2	9.3
Länder and local government institutions including higher education sector[2])	11.3	12.3	13.0	11.5	10.9	11.5	11.4	11.2
Private non-profit organisations[3])	35.5	34.8	38.0	38.6	41.5	41.5	41.6	41.1
Business enterprise sector	34.5	34.0	29.9	28.6	26.8	27.2	27.6	28.5
Abroad	10.3	11.0	10.6	12.1	11.3	10.1	10.2	9.9
Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
DM million	*14,106*	*15,215*	*16,927*	*17,339*	*16,860*	*16,348*	*16,938*	*17,613*

[1]) Estimated.
[2]) Excluding DFG basic funding and funds for special research programmes.
[3]) Including DFG basic funding and funds for special research programmes.
Source: BMBF

Rounding error

education sector in the new Länder and East Berlin from 1991 onwards this sector received additional federal funds under the University Renewal Programme (HEP). It should be noted that only an average R&D share of 30 % of the functional federal funds allocated to the higher education sector is included in this consideration.

In 1994 scientific non-profit organisations, including the German Research Foundation, were the largest recipient group with a share of 41.5 %. The better part of funds in this group went to national research centres which in 1994 received about DM 2.9 billion as basic funding and for financing specific projects. With about DM 2.7 billion research and science funding organisations are a close second. The trend beyond 1994 (actual) suggests that in the 1996 draft the levels of funds for these two recipient groups will converge.

The provisional or partly estimated breakdown of expenditure by recipient group in the 1995 budget indicates that the "Business enterprise sector", the second largest recipient group, will benefit from increased federal funding (cf. Table II/9).

From 1993 to 1994 the recipient group "Abroad" had to sustain a decline in funds. Its share dropped from 11.3 % (1993) to 10.3 % (1994). The data available for 1995 (budgeted) suggest that this share will not change substantially (cf. Table II/9).

A breakdown of the recipient group "Business enterprise sector" by industries shows that, with about 79 % (1994), businesses in the manufacturing sector (excluding the construction industry) received by far the highest percentage of federal funds. Within this sector expenditure focused on "Steel construction, mechanical engineering and vehicle construction" and "Electrical engineering, precision mechanics and optics" which together accounted for 60 % of federal R&D funding in the business enterprise sector. While the share of the manufacturing sector hardly changed compared with 1981 (81 %), that of "Utilities and mining" went down considerably. In 1981 it amounted to about 10 %, in 1994 it had shrunk to 1 %. The expenditure accounted for by "Services rendered by private businesses and the liberal professions" varied in the period under review; this sector has clearly gained in importance since 1981 as its share has more than doubled (1981: 8 %; 1994: 17 %).

In 1994 almost 11 % of federal funds was channelled to international scientific organisations; this percentage was down 0.6 % on the previous year. The better part went to international scientific organisations and research institutions in the form of membership fees. The European Space Agency (ESA) and the European Laboratory for Particle Physics (CERN) received the lion's share of these funds.

5. Share of basic research in research funding by the Federal Government

During the 1980s federal expenditure on basic research rose from DM 2.5 billion (almost 24 %) to DM 4.3 billion (1990: 28.2 %). In 1991 it was raised again to DM 4.9 billion or 29.1 %. In 1992 figures stabilised and the share of funds allocated to basic research in total federal R&D expenditure amounted to 29.2 % (DM 5.1 billion)[8].

Table II/10

Share of basic research in the federal R&D expenditure

Year	Federal R&D expenditure	Share of basic research	
	DM million		%
1981	10.447,8	2.484,2	*23,8*
1982	11.625,2	2.617,2	*22,5*
1983	11.515,1	2.781,5	*24,2*
1984	11.809,9	3.050,6	*25,8*
1985	12.834,7	3.243,3	*25,3*
1986	12.965,4	3.429,5	*26,5*
1987	13.221,8	3.581,5	*27,1*
1988	13.339,5	3.709,8	*27,8*
1989	14.105,5	3.973,4	*28,2*
1990	15.214,5	4.289,7	*28,2*
1991	16.926,5	4.930,6	*29,1*
1992	17.338,9	5.066,7	*29,2*

Source: BMBF

The trend of basic research after 1989 was influenced by the various special programmes aiming to maintain research capacities, especially in the higher education sector. Among these programmes are the programme for ensuring academic efficiency and access to overcrowded courses (HSP I) and the programme for ensuring efficiency in universities and research, and for promoting young scientists (HSP II) as well as financial assistance, pursuant to Article 104 a, para 4 of the Basic Law, to (old) Länder with weak structures to be invested in research and technology (1989 to 1992). Another influencing factor after 1991 has been expenditure related to schemes designed to develop a pan-German research system (cf. Section 4).

The individual funding areas have widely varying shares in basic research (cf. Table II/11). Above-average shares are held by "Large-scale equipment for basic research" (90.6 %), "Supporting organisations; restructuring of research in the new Länder; university construction and mainly university-related special programmes" (65.0 %), "Marine research and marine technology; polar research" (57.4 %) and "Biotechnology" (45.9 %). The percentage of basic research is also disproportionately high in "Humanities; economic and social sciences" (45.1 %), "Geosciences and raw material supply" (45.0 %) and "Research and development in the service of health" (38.7 %).

[8]) 1993 and 1994 data not available.

Table II/11

Share of basic research in federal R&D expenditure by funding area in 1992

	Funding area	R&D expenditure 1992 (DM million)	of which basic research (DM million)	% of basic research
A	Supporting organisations; restructuring of research in the new Länder; university construction and mainly university-related special programmes	2,602.0	1,692.5	*65.0*
B	Large-scale equipment for basic research	1,009.9	914.8	*90.6*
C	Marine research and marine technology; polar research	273.7	157.0	*57.4*
D	Space research and space technology	1,785.5	494.7	*27.7*
E	Energy research and energy technology	1,146.5	270.6	*23.6*
F	Environmental research; climate research	1,005.9	259.7	*25.8*
G	Research and development in the service of health	726.2	281.0	*38.7*
H	Research and development to improve working conditions	120.9	8.7	*7.2*
I	Information technology (including production engineering)	964.3	167.7	*17.4*
K	Biotechnology	353.4	162.1	*45.9*
L	Materials research; physical and chemical technologies	605.1	160.5	*26.5*
M	Aeronautical research and hypersonic technology	807.5	16.7	*2.1*
N	Research and technology for ground transport (including traffic safety)	226.4	5.3	*2.3*
O	Geosciences and raw material supplies	231.3	104.0	*45.0*
P	Regional planning and urban development; building research	174.2	10.7	*6.1*
Q	Research and development in the food sector	95.9	9.5	*9.9*
R	Research and development in agriculture, forestry and fishery	263.6	40.0	*15.2*
S	Educational research	130.3	–	–
T	Innovation and improved basic conditions	675.2	16.1	*2.4*
U	Specialised information	83.5	1.2	*1.4*
V	Humanities; economic and social sciences	453.4	204.4	*45.1*
W	Other activities not assigned to other sectors	538.8	89.0	*16.5*
A-W	Total civil funding areas	14,273.7	5,066.0	*35.5*
X	Defence research and technology	3,065.2	0.7	*0.0*
Total federal R&D expenditure		**17,338.9**	**5,066.7**	**29.2**

Source: BMBF

Rounding error

If civil funding areas alone are considered, it becomes apparent that more than one-third of federal R&D expenditure benefits basic research.

6. Expenditure of the Länder on science, research and development

Basic funds allocated to science by Länder and local governments which cover R&D expenditure as well as expenditure on R&D-related activities, especially teaching in the higher education sector amounted to about DM 30.7 billion (actual) in 1993; this is 6.1 % up on 1992 (DM 28.9 billion). The new Länder without East Berlin accounted for DM 4.4 billion (14.5 %), in 1992 their share was roughly 12.4 % (DM 3.6 billion). This high rate of increase (+24.2 %), however, is likely to be attributable to some degree to statistical methods since part of the science expenditure by the new Länder could not be registered completely due to the way in which it was accounted for in the Länder budgets in previous years (cf. Table II/12).

According to the budgeted data, which are provisional in part, basic funds of Länder and local governments allocated to science amounted to DM 32.5 billion in 1994 (up 6.1 % on 1993). In 1995 they will presumably increase to about DM 34.3 billion and hence be 5.4 % up on 1994 (cf. Figure II/7).

Science expenditure is broken down into two functions, "Higher education sector including university hospitals" which accounted for about 85.6 % of basic funds spent by Länder and local governments in 1993, and "Non-university science and research" which received 14.4 % of the funds.

This indicates a minor shift in favour of the non-university sector which in 1992 held a share of 14.2 %. In comparison with the 1989 data for the old Länder (13.2 %) this sector has grown considerably. According to the 1995 budget data its share will edge up again to 15.1 %.

"Basic funds for science" are based on the science expenditure (net expenditure) of Länder and local governments adjusted for direct revenues. With this concept it is possible to eliminate to a great extent (by subtracting the Länder revenues from patient care) the growing distortion of net expenditure caused by the funds spent on patient care in university hospitals.

In 1993, the last year for which mostly actual data are available, the expenditure by Länder governments on research and development amounted to a good DM 13.5 billion (of which an estimated 19 % is accounted for by the new Länder including East Berlin). Hence expenditure was up 5.1 % on 1992 (DM 12.9 billion) and up 10.2 % on 1991 (DM 12.3 billion) (cf. Table II/12). Estimates for subsequent years suggest a further increase to DM 14.3 billion (1994) and DM 15.1 billion (1995) which – compared with total

Table II/12

Basic funds*) allocated by Länder and local governments to sciences

– DM million –

Land	1989	1991	1992	1993	1994	1995
	actual				budget[1])	
Baden-Württemberg	3,230.3	3,665.9	3,999.2	4,114.4	4,598.8	4,555.7
Bavaria	3,274.0	3,898.9	4,406.2	4,399.3	4,784.9	5,123.9
Berlin[2])	1,722.4	2,594.2	2,858.2	3,248.3	3,105.2	3,280.0
Brandenburg	–	–	305.8	425.0	589.7	673.8
Bremen	266.5	322.4	334.0	368.9	336.9	392.7
Hamburg	784.7	863.5	965.3	1,039.3	972.3	1,210.0
Hessen	1,824.3	2,100.3	2,296.1	2,405.3	2,515.9	2,524.1
Mecklenburg-West Pomerania	–	–	400.1	475.9	669.2	704.4
Lower Saxony	1,944.0	2,238.7	2,526.9	2,644.2	2,551.3	2,654.5
North Rhine-Westphalia	4,650.3	5,198.2	5,685.8	5,679.5	5,928.2	5,967.9
Rhineland-Palatinate	874.2	990.7	1,045.0	1,045.4	1,127.3	1,205.6
Saarland	340.6	355.9	367.7	419.1	400.7	419.0
Saxony	–	–	1,489.8	1,740.1	2,041.1	2,200.6
Saxony-Anhalt	–	–	815.8	863.6	985.5	1,087.4
Schleswig-Holstein	712.8	868.1	825.8	847.2	952.6	1,070.6
Thuringia	–	–	568.5	943.4	977.6	1,215.4
Total	**19,674.3**	**26,416.5**	**28,890.2**	**30,658.9**	**32,537.0**	**34,285.6**
of which						
Old Länder and East Berlin	.	23,096.5	25,310.2	26,210.9	27,273.9	28,404.0
New Länder without East Berlin[3])	–	3,320.0	3,580.0	4,448.0	5,263.1	5,881.6
of which						
R&D expenditure of Länder[4])	*9,157*	*12,287*	*12,888*	*13,546*	*14,340*	*15,060*

*) Basic funds: net expenditure minus direct revenues (especially revenues from patient care in university hospitals).
[1]) Due to different estimating methods budgeted data are not fully comparable with actual data.
[2]) As from 1991 including East Berlin.
[3]) 1991 data estimated.
[4]) Estimated in some cases; based on actual figures up to and including 1993. From 1985 onwards only R&D shares of Länder research institutions included.

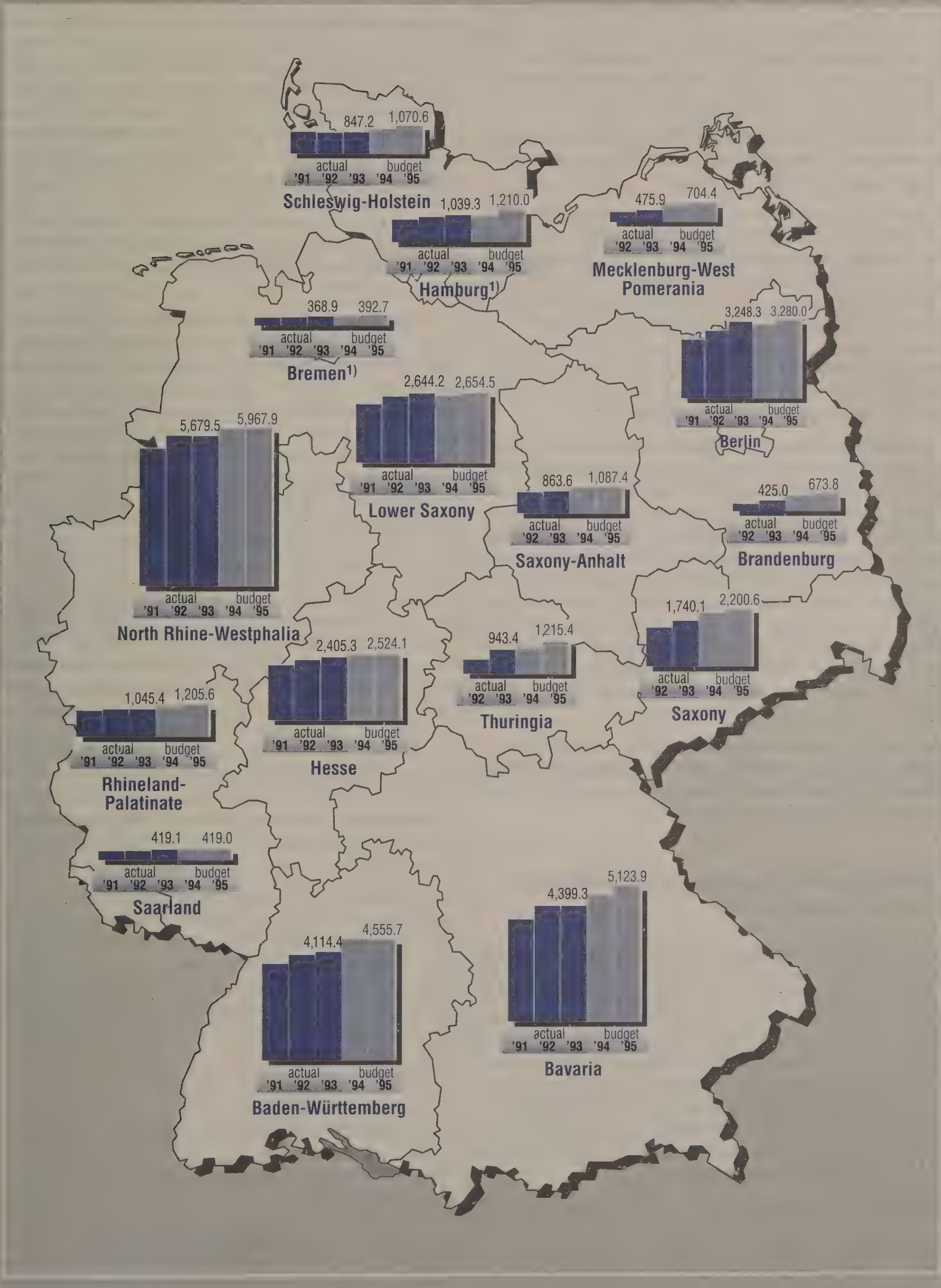
Source: Federal Statistical Office, BMBF

Rounding error

Figure II/7

Science expenditure by Länder and local governments

Basic funds*) of Länder and local governments in DM million



* Basic funds: net expenditure minus direct revenues (especially revenues from patient care in university hospitals).

1) The comparability of actual and budget figures is reduced.

Source: Federal Statistical Office, BMBF

BMBF, BuFo '96

German R&D expenditure – represents above-average growth.

Like basic funds for science, Länder R&D expenditure mainly goes to the higher education sector whose share in 1993 was a good 72 % (actual). The non-university sector received about 23 % of funds, the business enterprise sector just under 5 %. This implies that, compared with 1990, proportions shifted only slightly as at that time the share of the business enterprise sector amounted to 4 %.

When interpreting the data relating to Länder expenditure on R&D, the following special features need to be taken into account:

As described in detail in previous reports, the R&D expenditure of universities is determined by means of a computing procedure based on R&D coefficients. The basis of this computation is provided by data related to university expenditure broken down by subject, in conjunction with data or assumptions concerning specific activities of scientific personnel. From 1992 onwards this concept has also been applied to universities in the new Länder; the corresponding data for 1991 were estimated.

To complement these considerations which highlight the great impact that the "Higher education sector including university hospitals" has on the allocation of basic Länder funds for science (it received more than 85.6 % in 1993) it should be pointed out that the trend of basic funds allocated by the Länder to universities does not fully describe the development of the universities' financial resources. A sizeable proportion – which increased during the 1980s – of university research in particular is financed by external funds which are not included in basic funds, unless they are provided by the Länder themselves (cf. Section 8).

Total R&D expenditure by the higher education sector is also discussed in Section 2 in conjunction with Germany's gross domestic expenditure on R&D broken down by performing sectors.

7. Joint research funding by Federal and Länder governments

The Federal and Länder governments jointly finance research institutions or – in the case of the Academies of Sciences – research projects of supraregional and national interest. Joint research funding is based on Article 91 b of the Law and regulated by the Skeleton Agreement on Research Promotion of 28 November 1975, last amended on 8 November 1995. The various institutions are funded according to allocation keys agreed upon by the Federal and Länder governments (cf. Part I, Section 3.1). The institutions and projects funded on this basis comprise the

- Max Planck Society,
- Fraunhofer Society,
- German Research Foundation including special research programmes,
- national research centres ("Helmholtz Centres"),
- institutions included in the Blue List,
- Peace and Conflict Research Centre, Bonn,
- Deutsche Akademie Leopoldina as well as
- projects of the Academies of Sciences.

In 1994, the last year for which actual data are available, the institutions funded jointly by the Federal and Länder governments received a total of DM 7.7 billion (including the funds granted under the Special University Programme II (HSP II) and the University Renewal Programme (HEP)). The Federal Government's contribution to joint funding amounted to DM 5.3 billion, that is about 70 %, while the Länder governments allocated just under DM 2.4 billion (cf. Table II/13). The amounts budgeted for 1995 and 1996 are DM 8.1 billion and DM 8.4 billion, respectively, which implies an annualised rate of increase between 1994 and 1996 of 4.5 %.

National research centres receive the largest share of basic funding allocated to institutions. They are financed by the Federal Government and the host Land/Länder on a 90 : 10 basis. In 1994 they received total basic funding to the tune of just under DM 2.9 billion. The 1996 budget provides for DM 3.0 billion. With an annual growth rate of 1.2 % since 1994 the increase in funds enjoyed by the national research centres is clearly below the mean annual changes resulting for all institutions under consideration. As a result their share in total basic funding dropped from 37.5 % (1994) to 35.2 % (1996).

The second largest share in basic funding of institutions is accounted for by the *German Research Foundation (DFG)*. The Federal Government and all Länder governments contribute to its resources. General research funding and the Heisenberg Programme as well as professorial candidates are financed on a 50 : 50 basis, research programmes and the Leibniz Programme on a 75 : 25 basis (Federal Government: Länder governments) and postgraduate courses on a 65 : 35 basis. In 1996 the share in total basic funding of institutions accounted for by the DFG (including all special programmes) is DM 2.0 billion, that is 24.1 % (1994: 22.8 %).

The Federal Government and (all) Länder governments make equal contributions to financing the *Max Planck Society (MPG)*. With a total of DM 1.3 billion in 1994 basic funding of the MPG amounted to about three quarters of that of the DFG. The funds budgeted for 1995 and 1996 come to about DM 1.4 billion and DM 1.5 billion, respectively. Hence the MPG share in joint research funding has risen from 16.9 % (1994) to 17.7 % (1996).

As a result of the inclusion of research institutions of the former GDR – following recommendations made by the Science Council – the share of *Blue List institutions* has more than doubled. In 1991 there were 48 such institutions whose basic funding totalled about DM 500 million. By 1994 their number had risen to 84 and they received basic funding to the tune of DM 1.2 billion. With DM 1.3 billion the amount budgeted for 1996 is almost 11 % higher. In 1996 Blue List institutions account for 15.8 % of total basic funding (while in 1991 it was just under 9 %). With the

Table II/13

Joint funding of research by Federal and Länder governments, 1994 to 1996 (Basic funding of institutions)[1])

– DM million –

Institution	1994 actual			1995 budget			1996 budget		
	Total	Federal Government	Länder	Total	Federal Government	Länder	Total	Federal Government	Länder
Max Planck Society[2])	**1,303.9**	**648.8**	**655.1**	**1,432.3**	**718.2**	**714.1**	**1,485.2**	**739.9**	**745.2**
German Research Foundation[3])	**1,754.2**	**1,051.9**	**702.3**	**1,917.7**	**1,147.0**	**770.7**	**2,024.5**	**1,221.8**	**802.7**
of which:									
– general funding of research	1,122.7	600.8	521.9	1,203.4	643.7	559.7	1,280.1	692.3	587.8
– special research programmes	469.0	352.0	117.0	505.4	379.3	126.1	529.6	397.2	132.4
– Heisenberg Programme[3])	3.6	1.8	1.8	3.0	1.5	1.5	1.2	0.6	0.6
– funding and promotion of selected individual researchers and groups of researchers (Leibniz Programme)	27.0	20.2	6.8	27.0	20.2	6.8	27.0	20.2	6.8
– funding of postgraduate studies[3])	74.5	48.4	26.1	84.0	55.1	28.9	115.9	75.9	40.0
– funding of professorial candidates[3])	57.4	28.7	28.7	95.8	47.9	47.9	70.4	35.2	35.2
Peace and Conflict Research Centre, Bonn	**0.5**	**0.4**	**0.1**	**0.5**	**0.4**	**0.1**	**0.5**	**0.4**	**0.1**
Fraunhofer Society[4])	**491.8**	**408.5**	**83.3**	**525.1**	**418.2**	**106.9**	**539.5**	**426.4**	**113.1**
Projects of the Academies of Sciences[5])	**65.1**	**32.5**	**32.5**	**67.4**	**33.7**	**33.7**	**70.9**	**35.5**	**35.5**
National Research Centres	**2,884.5**	**2,581.1**	**303.3**	**2,899.1**	**2,596.6**	**302.8**	**2,956.6**	**2,647.2**	**309.3**
of which:									
– Alfred Wegener Institute for Polar and Marine Research, Bremerhaven (AWI)	104.4	93.8	10.5	108.7	97.7	11.0	112.9	101.5	11.4
– German Electron Synchrotron, Hamburg (DESY)	287.8	259.0	28.8	278.2	250.4	27.8	282.4	254.2	28.2
– German Aerospace Research Establishment, Cologne (DLR)[6])	415.2	372.4	42.9	406.7	365.9	40.8	416.8	375.0	41.8
– German Cancer Research Centre, Heidelberg (DKFZ)	151.2	136.1	15.1	155.5	140.0	15.6	161.7	145.5	16.2
– Biotechnological Research Company Ltd., Braunschweig-Stöckheim (GBF)	61.1	50.8	10.4	65.6	59.1	6.6	63.2	56.9	6.3
– Geoscientific Research Centre, Potsdam (GFZ)	78.0	69.4	8.5	77.6	69.0	8.6	81.5	72.1	9.3
– GKSS-Geesthacht Research Centre, Ltd., Geesthacht (GKSS)	115.0	103.5	11.5	106.7	96.1	10.7	111.2	100.1	11.1

cont. Table II/13

Institution	1994 actual			1995 budget			1996 budget		
	Total	Federal Govern-ment	Länder	Total	Federal Govern-ment	Länder	Total	Federal Govern-ment	Länder
– GMD – Mathematics and Data Processing Company Ltd., St. Augustin near Bonn (GMD)	130.1	117.1	13.0	127.8	115.0	12.8	129.4	116.5	12.9
– GSF – Environmental and Health Research Centre Ltd., Neuherberg near Munich (GSF)	154.1	140.0	14.1	151.1	137.3	13.8	151.6	137.4	14.2
– Heavy Ion Research Centre Ltd., Darmstadt (GSI)	125.1	112.6	12.5	125.5	113.0	12.6	127.2	114.5	12.7
– Hahn-Meitner Institute Berlin Ltd., Berlin (HMI)	114.4	102.9	11.4	113.3	101.9	11.3	114.2	102.8	11.4
– Max Planck Institute for Plasmaphysics, Garching near Munich (IPP)	97.7	89.5	8.2	106.0	95.3	10.6	110.0	99.0	11.0
– Jülich Research Centre Ltd., Jülich (KFA)[7])[8])	471.4	413.6	57.8	459.3	402.6	56.7	470.4	412.0	58.4
– Karlsruhe Research Centre Ltd., Karlsruhe (FZK)[7])	423.2	380.9	42.3	424.7	382.3	42.4	432.1	389.0	43.1
– Max Delbrück Centre for Molecular Medicine, Berlin-Buch (MDC)	97.0	86.8	10.2	93.4	83.1	10.3	95.6	85.3	10.3
– Environmental Research Centre Ltd., Leipzig-Halle (UFZ)	58.8	52.7	6.1	99.0	87.9	11.2	96.4	85.4	11.0
Blue List Institutions[3])	**1,194.0**	**619.3**	**574.8**	**1,299.6**	**667.5**	**632.1**	**1,324.2**	**679.5**	**644.6**
Deutsche Akademie Leopoldina, Halle/Saale	**2.4**	**1.9**	**0.5**	**2.6**	**2.1**	**0.5**	**2.7**	**2.1**	**0.5**
Total	**7,696.4**	**5,344.4**	**2,351.9**	**8,144.3**	**5,583.7**	**2,560.9**	**8,404.1**	**5,752.8**	**2,651.0**

[1]) The above amounts also include funds provided on the basis of special agreements concluded by Federal and Länder governments; this results in deviations from the allocation keys laid down in the Skeleton Agreement on Research Promotion pursuant to Article 91 b of the Basic Law.
[2]) Including special funds allocated under Special University Programme II and the University Renewal Programme.
[3]) Including special funds appropriated for DFG by the Federal or Länder governments.
[4]) Excluding basic funding by the Federal Ministry of Defence as these resources are not subject to joint funding by Federal and Länder governments.
[5]) Project funding.
[6]) Excluding a DM 24 million lump-sum payment by the Federal Ministry of Defence as this payment is not subject to joint funding by Federal and Länder governments.
[7]) Excluding funds earmarked for decommissioning and disposing of nuclear and other facilities.
[8]) Including the Institute for Biotechnology which is 100 % financed by North Rhine-Westphalia.

Source: Federal/Länder Commission for Educational Planning and Research Promotion, DFG, economic plans published in the 1996 federal budget, BMBF calculations

Rounding error

exception of service institutions to which different allocation keys apply, the majority of these institutions are funded by the Federal Government and the respective host Land on a 50 : 50 basis.

With DM 492 million (1994, actual) and DM 540 million (1996, budgeted) the share in basic funding of institutions of the Fraunhofer Society (6.4 %) remained unchanged in the period under review. The allocation key agreed upon for this type of institution is the same as for national research centres, i.e. the Federal Government contributes 90 %, the respective host Land/Länder 10 %.

Finally, joint funding also includes the *Peace and Conflict Research Centre, Bonn, the Deutsche Akademie Leopoldina, Halle/Saale,* as well as *the projects of the Academies of Sciences.* The funds allocated to these institutions by the Federal and Länder governments are considerably lower than the sums mentioned above: In 1994 they received a total of DM 68.0 million, in 1996 DM 74.1 million. With an annual growth rate of about 4.4 % the increase in funds allocated to these institutions between 1994 and 1996 is almost the same as that averaged over all institutions under consideration.

8. Resources for research and development in the higher education sector

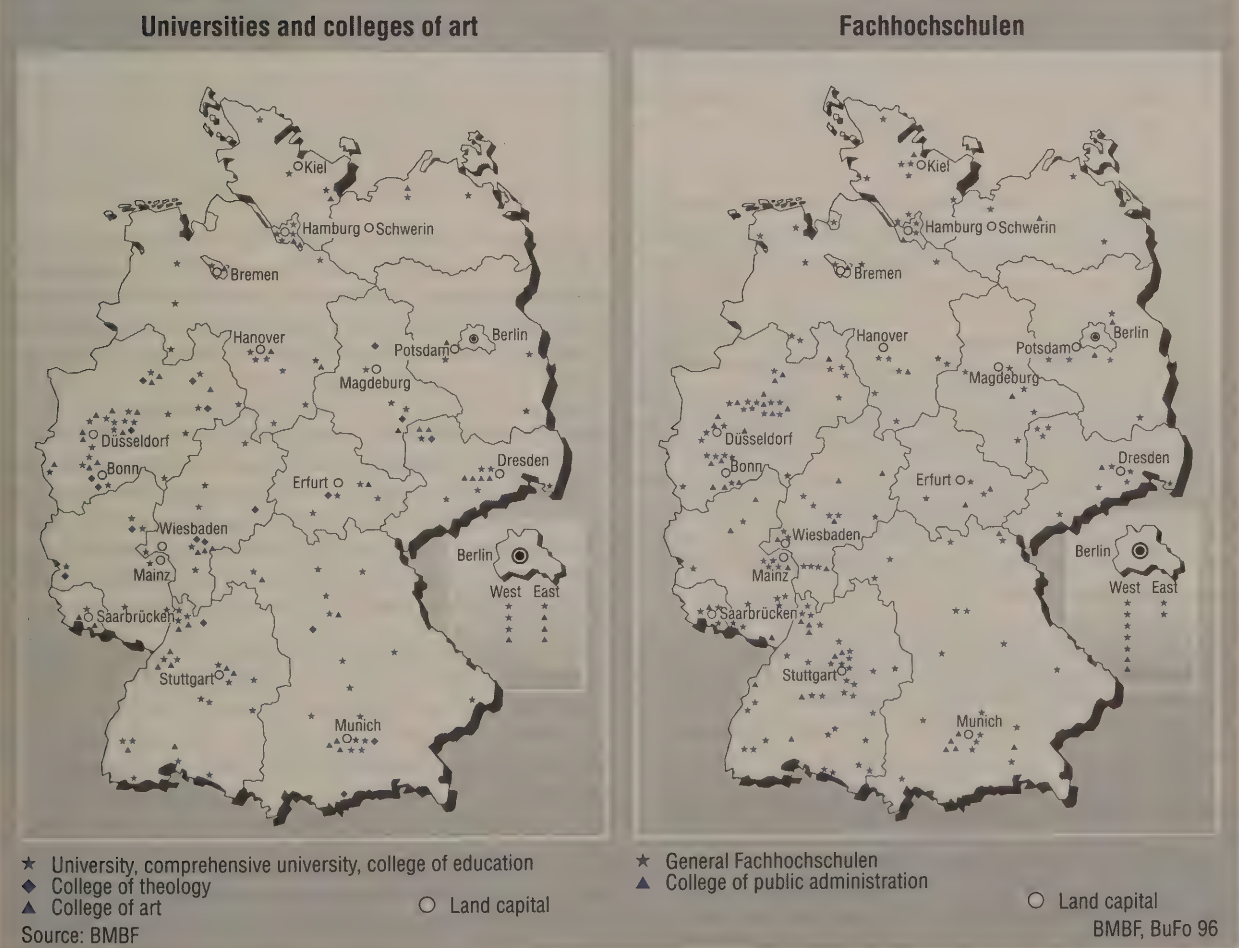
In 1995 there were 329 state, or officially recognised, institutions of higher education in Germany; of these 113 were universities and comparable institutions (89 universities, one comprehensive university, 17 colleges of theology and 6 colleges of education), 46 colleges of art, 139 general Fachhochschulen and 31 colleges of public administration. 67 of these 329 higher education institutions (1995) were privately funded, with more than half being denominational institutions. (The regional distribution of universities and Fachhochschulen is shown in Figure II/8).

In 1995 about three quarters of a total of 1.9 million students were enrolled at universities or comparable institutions, almost 25 % attended courses at Fachhochschulen.

Information relating to higher education R&D personnel and financial resources is based on data collected for higher education statistics on total full-time higher education personnel and expenditure:

Figure II/8

Locations of higher education institutions 1994



In 1993, the last year for which actual data on full-time higher education personnel are available, 366568 persons (full-time equivalent, FTE) were working in this sector. In 1991 it was 362501 persons (FTE) (including the estimate for Germany's new Länder). Almost 40 % was scientific and artistic staff, while a good 60 % was accounted for by administrative, technical and other supporting staff. Data on the percentage of women in the group of scientific staff are also available. In 1993 20.3 % of the scientific staff was female (old and new Länder), compared with 18.0 % in 1991 (old Länder).

Data on total expenditure in the higher education sector are available with breakdowns. The data collected for the financial statistics of the higher education sector (including university hospitals) cover all personnel expenditure, operating expenditure and capital expenditure. According to these statistics higher education expenditure in 1993 totalled DM 44.7 billion. A substantial percentage of this outlay is accounted for by university hospitals. It is not taken into account, however, that part of this expenditure, i.e. cost incurred due to patient care, is offset by revenues (daily rates to be paid in hospitals). To avoid any distortions not only direct expenditure is determined, but also the aggregate "expenditure on education and research" which covers higher education expenditure minus revenues resulting from non-education and non-research activities.

Actual data are available up to and including 1993 as well as estimates for 1994 and 1995. Accordingly, expenditure on education and research in the higher education sector in 1993 amounted to DM 31.0 billion; the estimate for 1995 is DM 33.7 billion. This equals a total increase of 8.6 % (old Länder: 7.1 %; new Länder: 15.7 %).

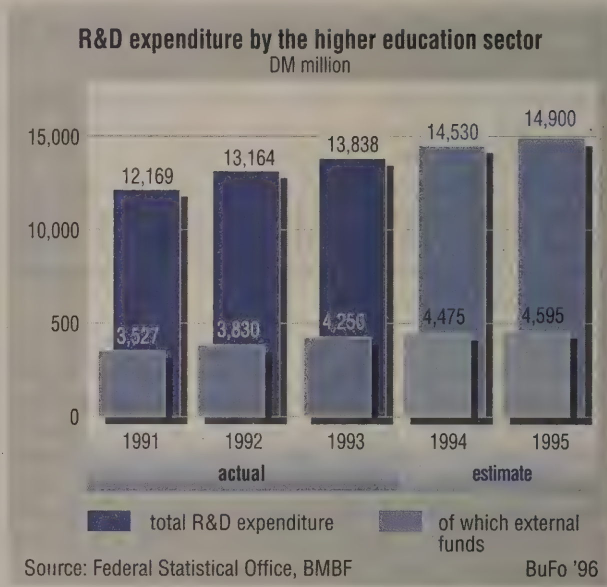
The share of Fachhochschulen rose considerably in recent years from 9.4 % in 1991 to 11.9 % in 1993 and 12.3 % in 1995. In the new Länder it was 13.7 % in 1993.

Central institutions being disregarded in this context, medicine as a scientific field accounted for the highest amount in 1993 (DM 7.2 billion). With DM 5.6 billion the expenditure on education and research in the humanities and the social sciences exceeded that of natural sciences by 9.1 %. The corresponding expenditure in engineering sciences (DM 4.3 billion) is considerably lower, with almost one-third being accounted for by Fachhochschulen, especially in the field of agricultural science (DM 1.0 billion).

Using these personnel and financial data a special computation procedure involving R&D coefficients is applied in these research statistics to determine higher education R&D personnel and financial resources.

Accordingly, expenditure on R&D in the higher education sector in 1993 totalled DM 13.8 billion; this is about 45 % of total expenditure on teaching and research (cf. Figure II/9). The estimate for 1995 was some DM 14.9 billion, up 7.7 % on 1993. Natural sciences accounted for the largest share (DM 3.9 billion

Figure II/9



or 28.1 % of total R&D expenditure in higher education). The R&D expenditure on medical sciences is slightly lower (DM 3.7 billion) but still far ahead of that of the social sciences and humanities (DM 2.7 billion). The higher education sector is financed by the Länder governments which provide the better part of basic funds for education and research, the Federal Government, especially under university construction schemes (external funds; cf. Section 4), as well as the business enterprise sector and other providers of external funds, including the "abroad" sector. The contribution by external funds has grown continuously in recent years: in 1995 it will be some DM 4.6 billion (just under 31 %) (1991: 29 %).

Applying the above computation procedure involving R&D coefficients, the number of R&D personnel is also determined in these R&D statistics. In 1993 there were 110,020 people (FTE), which was about one-third of total full-time staff in the higher education sector. 16,680 FTE were accounted for by the new Länder, up 5.9 % on 1991. The corresponding figure for the old Länder was an above-average 10.6 %. The new Länder registered a decline of 14.5 % in 1991 and 1993 which is a slightly weaker decrease than in the other sectors in that part of Germany. It has to be taken into account, however, that the 1991 data are estimates; a survey as in the old Länder was not yet possible in that first year after unification.

With 30,980 FTE medical sciences had the highest number of R&D personnel in 1993. Only slightly below that level were natural sciences with 29,410 FTE, followed at a clear distance by the humanities and social sciences (25,540 FTE) and engineering sciences (20,910 FTE).

It is interesting to compare the trend of higher education resources with the development of funds available to institutes associated with universities („an-Institute") as both are closely interlinked. Actual 1993 data show an increase in R&D expenditure of affil-

iated institutes to just under DM 560 million, which is 17.2 % up on 1992. R&D activities of these institutes focused on natural sciences (37.6 %).

9. Research and development in the business enterprise sector

9.1 R&D resources in the business enterprise sector

Introduction

In 1993 there was a total of about 11,500 businesses doing research work in Germany, of which some 9,200 were based in the old Länder and 2,300 in the new Länder (including East Berlin). About 90 % of these research-performing companies employed fewer than 500 people each and thus fell into the group of small and medium sized enterprises (SMEs). But since a considerable number of companies is engaged in research on a regular, albeit discontinuous basis – i.e. a completed R&D project is not immediately followed by the next one – these data should rather be considered a snapshot of the 1993 situation[9]). It is assumed that the research potential of the business enterprise sector is much greater. Estimates made elsewhere suggest a total of about 25,000 companies.

R&D in the business enterprise sector is mainly performed in companies; but one must also consider the institutions for cooperative research and experimental development. These mainly include institutes set up by research groups formed by mid-size companies which make up the Confederation of Industrial Research Associations (AiF). Today there are 107 such research associations with 57 institutes of their own.

With 85 % of total intramural business enterprise expenditure on R&D large companies spent most of the resources, followed by SMEs with some 14 % (their share is rising) and the institutions for cooperative research and experimental development with about 1 %.

Looking at total expenditure on R&D in Germany (cf. Section 2) one can see how important the business enterprise sector is for R&D: With shares of 61 % (financing) and 66 % (performance) in gross domestic expenditure on R&D in 1995 this sector is the quantitatively most significant R&D player in Germany. A comparison with the other G7 states shows that in terms of performing R&D this also applies to all other major industrialised countries (cf. Section 10).

[9]) Data relating to financial and human R&D resources in the business enterprise sector are regularly collected and evaluated by SV-Wissenschaftsstatistik GmbH (SV-WiStat). At present final actual data are available up to and including 1993. For 1994, as for the previous even years, estimates were made on the basis of a limited survey. This exercise also produced 1995 target data for financial R&D resources (cf. Tables II/14 and II/15).

Business enterprise expenditure on R&D

A central indicator to describe the R&D activities of the business enterprise sector is R&D expenditure (cf. Table II/14). *Intramural R&D expenditure* are all expenditure for R&D performed in the business enterprise sector, whatever the source of funds. *Extramural R&D expenditure* of the business enterprise sector covers those funds which are allocated by a company or an institution for cooperative research and experimental development to R&D which is performed outside the organisation financing it (especially R&D contracts and R&D cooperations)[10]).

In 1993, the last year for which actual data are available, intramural R&D expenditure in the German business enterprise sector (domestic concept) totalled DM 51.2 billion. This is slightly down on 1991 in nominal terms. The target figures reported by industry suggest that in 1995 funds were up 1.8 % on 1994.

While in the early 1980s intramural R&D expenditure in the business enterprise sector had double-digit increase rates which were considerably higher than those of government expenditure and this growth slowed down considerably during the last third of the past decade, the first half of the 1990s is characterised by a stagnation of this indicator. Whether the moderate increase in 1995 over 1994 is the first sign of a turnaround remains to be seen. A similarly slackening dynamism in R&D expenditure is today also identifiable in the other major industrialised nations (cf. Section 10).

Intramural R&D expenditure in SMEs in Germany seems to follow an "acyclical" trend compared with the business enterprise sector as a whole. From 1991 to 1993 expenditure rose by 7 % and in 1994, according to current estimates, was up 4.6 % on the previous year (data for 1995 are not yet available). As a result of this disproportionately high increase the share of SMEs in total intramural R&D expenditure in industry went up from 12.4 % in 1991 to 14.1 % in 1994. The decline in the SMEs' share that was typical of the late 1980s was thus completely reversed in the 1990s.

Breaking down these funds by region, i.e. the old Länder on the one hand and the new Länder on the other, shows that this positive trend for SMEs results mainly from a corresponding development in the new Länder where the SME share in intramural R&D expenditure rose by 31.5 % between 1991 (DM 866 million) and 1993 (DM 1,139 million). During this period West Germany had a growth of 3.1 %.

This effect is much more marked for institutions for cooperative research and experimental development which account for about 1 % of total intramural R&D expenditure in the business enterprise sector. The

[10]) "Total R&D expenditure" covers both intramural and extramural R&D expenditure. When interpreting these statistics it should be noted that this aggregate includes double counting since extramural R&D expenditure can at the same time also be intramural R&D expenditure, i.e. in those cases where R&D is financed by one unit of the business enterprise sector and performed by another one.

Table II/14

R&D expenditure in the business enterprise (BE) sector

Parameter	in	Intramural R&D expenditure *)			
		1991	1993	1994	1995
		actual		estimate	budget
Business enterprises	DM million	50,794	50,154	50,108	.
of which SMEs¹):					
– in absolut terms	*DM million*	*6,306*	*6,749*	*7,061*	.
– percentage	%	*12.4*	*13.5*	*14.1*	.
IfG²)	DM million	538	567	567	.
Total BE³)	**DM million**	**51,675**	**51,236**	**51,190**	**52,120**
– percentage of (adjusted) gross value added in BE	%	2.3	2.1	2.0	.
– per labour force in BE	DM	1,771	1,839	1,856	.
– percentage of R&D expenditure of all sectors⁴)	%	69.3	66.8	66.0	.
– self-financing ratio	%	87.1	89.0	.	.
of which:					
old Länder (including West Berlin)					
– BE	DM million	48,905	48,207	.	.
of which SMEs¹):					
– in absolute terms	DM million	*5,440*	*5,609*	.	.
– percentage	%	*11.1*	*11.6*	.	.
– IfG²)	DM million	489	437	.	.
Total	DM million	**49,394**	**48,644**	**.**	**.**
– percentage of (adjusted) gross value added in BE	%	2.3	2.2	.	.
– per labour force in BE	DM	2,097	2,092	.	.
– percentage of R&D expenditure of all sectors⁴)	%	72	70	.	.
new Länder (including East Berlin)					
– BE	DM million	1,889	1,947	.	.
of which SMEs¹):					
– in absolute terms	DM million	*866*	*1,139*	.	.
– percentage	%	*45.8*	*58.5*	.	.
– IfG²)	DM million	49	130	.	.
Total	DM million	**1,938**	**2,077**	**.**	**.**
– percentage of (adjusted) gross value added in BE	%	1.3	0.9	.	.
– per labour force in BE	DM	345	451	.	.
– percentage of R&D expenditure of all sectors⁴)	%	41	34	.	.

Parameter	*in*	*Intramural R&D expenditure *)*			
		1991	*1993*	*1994*	*1995*
		actual		*estimate*	*budget*
Business enterprises	*DM million*	*5,548*	*6,875*	*7,382*	.
of which:					
– to BE	%	*64.4*	*66.7*	.	.
– to government and other national institutions	%	*18.6*	*15.5*	.	.
– abroad	%	*16.9*	*17.9*	.	.
IfG²)	*DM million*	*196*	*190*	*190*	.
Total BE	*DM million*	*5,744*	*7,066*	*7,572*	*7,767*

*) Intramural R&D expenditure: all expenditure for R&D performed in the business enterprise sector, whatever the source of funds. Extramural R&D expenditure: all expenditure on R&D performed outside the business enterprise sector.

¹) SMEs: small and medium-sized enterprises.

²) IfG: institutions for cooperative research and experimental development.

³) Including funds not related to specific items which after national consultation are added to the business enterprise sector; 1994 and 1995 provisional.

⁴) Business enterprise, higher education and non-university sectors; estimates.

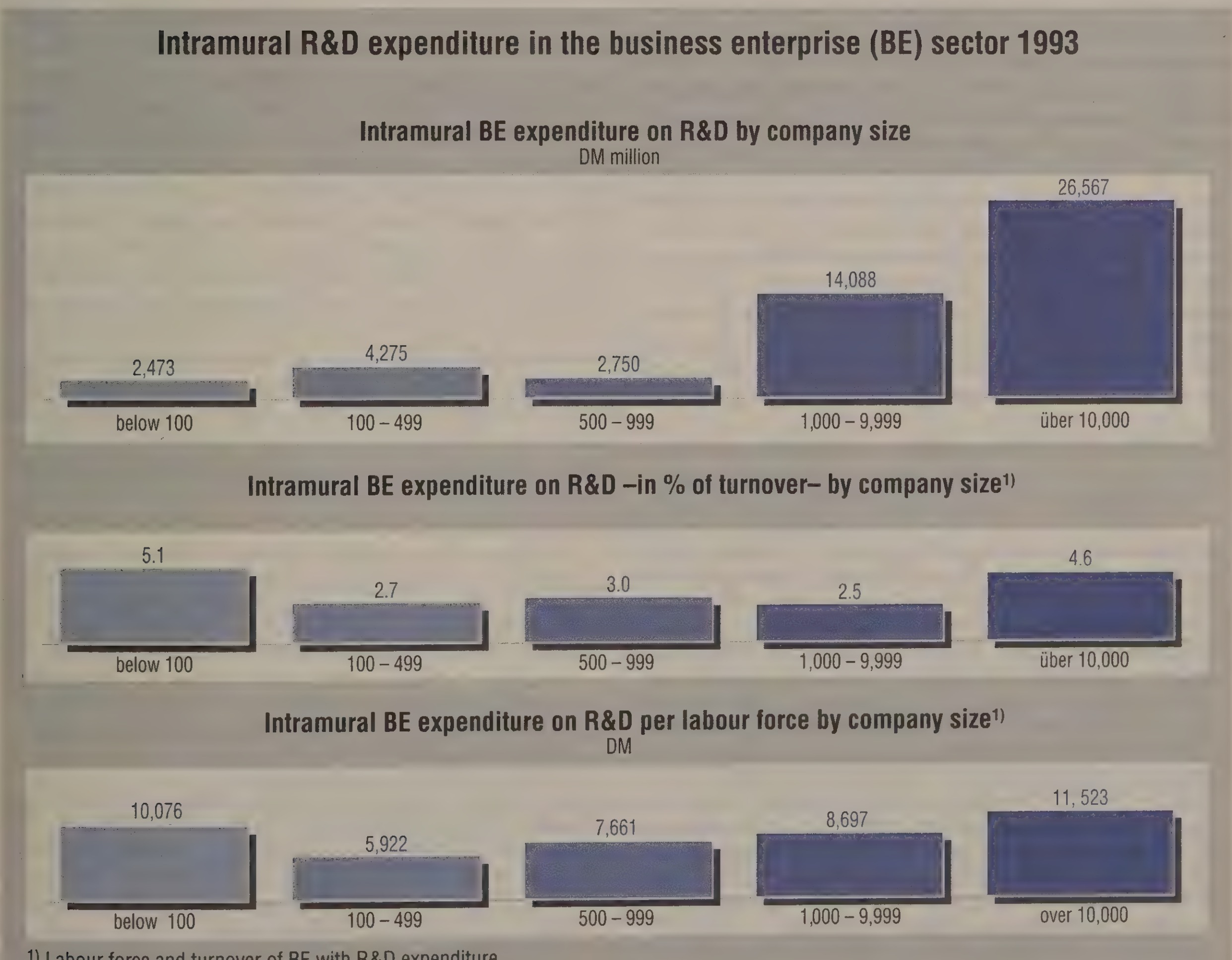
Source: SV-Wissenschaftsstatistik GmbH, Federal Statistical Office, BMBF calculations — Rounding error

positive rate of change of 5.4 % of intramural R&D expenditure from 1991 to 1993 is exclusively attributable to the new Länder: As such institutions were set up and expanded intramural R&D expenditure almost tripled (DM 49 million in 1991; DM 130 million in 1993). In the old Länder, however, only just under DM 440 million was spent on performing R&D in institutions for cooperative research and experimental development in 1993 which was some DM 50 million less than in 1991.

The comparison of the growth rates of intramural R&D expenditure with those of gross value added in the business enterprise sector shows that in recent years industry has slowed down its R&D activities much more than one would have been led to believe in view of the cyclical restrictions reflected in a rather moderate increase in gross value added. As a result the share of R&D expenditure in gross value added dropped from 2.3 % in 1991 to 2.0 % in 1993. This result, however, is not confirmed when one looks at intramural R&D expenditure as a percentage of turnover of R&D-performing companies, taking it as a characteristic ratio, which in this context is a common R&D statistics approach. At 3.5 %, this percentage – which reflects R&D intensity – has basically remained unchanged since 1987.

The stagnating trend which in the first half of the 1990s characterised financial R&D commitment in the business enterprise sector as a whole is the result of different developments in the various industries. With a good 40 % – and a slightly increasing trend over the period from 1991 to 1995 – almost half of intramural R&D expenditure in the business enterprise sector was accounted for by the steel and mechanical engineering and vehicle construction industries. The electrical engineering, precision mechanics and finished metal goods industries held the second largest share of about 27 %, followed by the chemical and mineral oil refining industries with nearly 20 %. Consequently, these three sectors accounted for 90 % of total funds spent on performing R&D in the business enterprise sector. Between 1991 and 1995 R&D expenditure by the chemical and mineral oil refining industries fell by 5 %. With –2 % electrical engineering, precision mechanics and finished metal goods also had a rate of change below the average of the business enterprise sector as a whole. The steel and mechanical engineering and vehicle construction in-

Figure II/10



1) Labour force and turnover of BE with R&D expenditure.
Source: SV-WiStat GmbH, BMBF calculations

BMBF, BuFo '96

dustries were the only sector with an above-average development. With an increase of almost 4 % it ensured that intramural R&D expenditure in the entire business enterprise sector rose in nominal terms between 1991 and 1995. Within the steel and mechanical engineering and vehicle construction industries it was primarily the automotive industry which produced the positive rate of change of +23 %. With –6 % mechanical engineering which is also part of this sector had a higher negative balance than the chemical industry[11]).

In the period from 1991 to 1995 the "Other services" industry had the highest growth rate in the entire business enterprise sector. In 1995 almost DM 1.4 billion were budgeted for R&D in this industry, while in 1991 actual expenditure amounted to DM 940 million. This was an increase of 44 %. The factors contributing to this development were, first – and this is by far the predominant component – discontinuous research in companies (i.e. in 1991 some businesses in this industry did not perform any R&D) and, second, the fact that some companies were reassigned to other industries (i.e. in 1993 these companies were for the first time assigned to "Other services", while in previous years they had usually been assigned to an industry in the manufacturing sector).

The development in the various industries also confirmed the positive turnaround which in 1995 could be identified for the entire business enterprise sector: While in 1993 – with the exception of the non-metallic minerals industry – all nine industries forming part of the manufacturing sector reduced their R&D expenditure compared with 1991, the R&D funds budgeted for 1995 by six of these nine industries were higher than the actual expenditure in 1993, albeit in some cases only slightly higher. R&D intensity in the individual industries varied widely. Except for an extremely high R&D share in turnover of R&D-performing companies in the aerospace industry (24 %), it was again the three industries mentioned above (i.e. chemical, automotive and electrical engineering industries) which could boast above-average levels[12]).

Development in the new Länder was as follows:

In 1991 3.8 % (about DM 1.9 billion) of total intramural business enterprise expenditure on R&D was accounted for by the new Länder. In 1992 this share dropped sharply to less than 3 %, with expenditure totalling about DM 1.5 billion. Today the rapid reduction in R&D capacities in East Germany in the wake of unification seems to have come to a halt: The 1993 expenditure of DM 2.1 billion is a good 35 % up on 1992. But even this high rate of increase was not enough to bring R&D intensity in the business enterprise sector in the new Länder up to West German levels (in this context one should also note the different – but now changing- salary levels in the old and new Länder). In 1993 expenditure per economically active person in the new Länder was DM 451, while in the old Länder it was DM 2,092. Also in terms of share in gross value added in the business enterprise sector the level in the old Länder was more than twice as high as in the new Länder (2.2 % compared with 0.9 % in 1993).

Another important difference between the old and the new Länder is the quantitative significance of SMEs. As shown in Table II/14, in 1993 almost 60 % of intramural business enterprise expenditure on R&D in the new Länder was accounted for by SMEs, while the corresponding figure for the old Länder was only about 10 %.

As mentioned above, financial R&D resources of the business enterprise sector comprise both intramural and extramural R&D expenditure. The total volume of the latter of about DM 7 billion is low, compared with the former. However, their development in the period under review shows that their relative importance was increasing continuously. In 1994 companies and institutions of cooperative research and experimental development spent DM 7.6 billion on extramural R&D, that is about one-third more than in 1991. Unlike the growth of intramural R&D expenditure in the business enterprise sector and institutions of cooperative research and experimental development this increase was the exclusive result of a corresponding overall development in the old Länder. The share held by the new Länder in total extramural R&D expenditure was negligible in comparison[13]). A

[11]) In addition to this development which deserves special attention it is the marked decline in the chemical industry's R&D expenditure which corroborates the hypothesis that these statistics reflect the development and acquisition of research capacities in other countries as well as the performance of biotechnological research abroad.

[12]) In addition to a breakdown by industry, the regional breakdown of R&D resources in the business enterprise sector is also quite informative. Intramural business enterprise expenditure on R&D in Baden-Württemberg and Bavaria amounted to DM 25.5 billion in 1993, that is nearly half of the total business enterprise R&D expenditure. 80 % of these funds went to the steel and mechanical engineering and vehicle construction industries as well as the electrical engineering, precision mechanics and finished metal goods industries; that is two thirds of total funds spent on performing R&D in those industries. The second highest total is just under DM 9 billion for North Rhine-Westphalia – about the sum accounted for by the electrical engineering, precision mechanics and finished metal goods industries alone in Baden-Württemberg and Bavaria. This means that North Rhine-Westphalia's expenditure is about DM 1 billion higher than the R&D expenditure of the region consisting of Hesse, Rhineland-Palatinate and the Saarland taken together. The chemical and mineral oil refining industries are particularly strong in both regions with more than DM 3 billion in each. In addition, North Rhine-Westphalia is the state in which institutions of cooperative research and experimental development play the most important role: About 50 % of intramural R&D expenditure of all institutions of cooperative research and experimental development is accounted for by this Land alone.

[13]) At present, there are no data available relating to the shares in extramural R&D expenditure accounted for by the old and the new Länder, because only R&D performance data (intramural R&D expenditure, R&D personnel) are broken down by R&D location (regionalisation by Länder). If the shares of the old and the new Länder in total 1993 intramural R&D expenditure in Germany are applied to extramural R&D expenditure, the relations indicated here will result.

breakdown by industry shows that the importance of R&D cooperations and contracts in the various industries more or less corresponded to that of intramural research. Also in the case of extramural R&D expenditure about 90 % was accounted for by the chemical and mineral oil refining industries, the steel and mechanical engineering and vehicle construction industries as well as the electrical engineering, precision mechanics and finished metal goods industries taken together. The better part of extramural R&D expenditure which rose between 1991 and 1993 to nearly two-thirds remained in the business enterprise sector itself, about 15 % was used for contracts and cooperations with public institutions and a slightly higher share was accounted for by abroad. In this context, however, it should be explained that the shares of the "Abroad" sector (about DM 1.2 billion in 1993) covered only those amounts that were appropriated by German companies or institutions for cooperative research and experimental development for performing R&D abroad (for globalisation of R&D cf. Section 9.3 as well as Part I, Section 2.2).

R&D personnel in the business enterprise sector

The surveys conducted regularly to determine the R&D resources of the business enterprise sector cover not only R&D expenditure, but also data relating to R&D personnel on a full-time equivalent (FTE) basis (cf. Table II/15).

In 1993, the last year for which actual data for the business enterprise sector are available, a total of 293,774 persons worked in R&D in that sector. That was about 28,000 fewer or an annualised 4.3 % less than in 1991 (321,756 FTE). The estimates for 1994 (284,380 FTE) suggest that there was another drop compared with the previous year, but at –3.2 % it was not as marked as in the years before which is confirmed by the emerging turnaround in intramural R&D expenditure.

Compared with other major industrialised countries (G7 states), a very high proportion of total R&D personnel in Germany, i.e. 62 %, was working in the business enterprise sector in 1993. A similarly high level was only reached by Japan, while some of the other G7 states stayed considerably below this level[14]).

R&D personnel consists of researchers, technicians and other supporting staff. The decline between 1991 and 1993 affected the group of researchers – which is of particular interest in this respect – to the same extent as it hit R&D personnel as a whole. The situation had been different in the two previous years (only true for the old Länder). From 1989 to 1991 the absolute decline in business enterprise R&D personnel by a total of 3.1 % was accounted for by an 8 % negative change in the group of technicians and other supporting staff and an increase of 5 % in the researcher group.

[14]) France: 52 %; UK: 59 %; Italy: 44 %; Canada: 47 %; USA: not available (cf. Section 10).

In the period from 1991 to 1993 the reduction of R&D personnel of 7.5 % in the institutions of cooperative research and experimental development was only slightly less marked than in the business enterprises. Like the development of intramural R&D expenditure, this reduction was accounted for by a disproportionate decline in the old Länder (1991: 4,062; 1993: 3,315) and an increase in the new Länder (1991: 919; 1993: 1,291).

The special role that SMEs play in the development of financial R&D resources also applies to R&D personnel. The decline in the number of total business enterprise R&D personnel of 8.7 % (1993/1991) and 3.2 % (1994/1993) compared with relatively moderate rates of change of –4.6 % and –0.5 %, respectively, in SMEs. Separate appraisals of the old and the new Länder show – even though only data up to and including 1993 are available – that in West German SMEs relatively fewer R&D staff were shed (–3.3 %) than in the business enterprise sector as a whole. The rate of change of SMEs in the new Länder, on the other hand, tallies with the average. This, too, suggests that increases in R&D expenditure in this part of the business enterprise sector in the new Länder, as described above, were primarily caused by high a investment outlay.

The largest shares of total R&D personnel – without any changes in the period under review – were accounted for by steel and mechanical engineering and vehicle construction with 40.5 %, electrical engineering, precision mechanics and finished metal goods with 30.8 % and the chemical and mineral oil refining industries with 17.7 % (1994). In steel and mechanical engineering and vehicle construction as well as the chemical and mineral oil refining industries these figures were slightly below the corresponding shares of intramural R&D expenditure in that year, while the share of electrical engineering, precision mechanics and finished metal goods is three percentage points higher. The "ranking" resulting from these rates of change tallies with that resulting from intramural R&D expenditure. In the chemical and mineral oil refining industries R&D personnel was reduced by nearly 20 % from 1991 to 1994 which was the greatest decrease of all industries, while steel and mechanical engineering and vehicle construction, with –6 %, have the lowest reduction rate of all industries[15]).

Taken together, the new Länder accounted for 7.5 % of R&D personnel in 1993 which is a considerably

[15]) The dominating position of Baden-Württemberg and Bavaria (50 %) which resulted from the breakdown of R&D expenditure by region is less strong with 47 % when it comes to R&D personnel. The highest share with more than 66,000 persons is accounted for by the steel and mechanical engineering and vehicle construction industries which hence have considerably more R&D personnel than North Rhine-Westphalia which with 48,431 ranks third on this list. As indicated with regard to intramural R&D expenditure the relative focus of R&D capacity in this latter Land is on the chemical and mineral oil refining industries. It is only in Hesse, Rhineland-Palatinate and the Saarland taken together that these industries employ more R&D personnel (22,405) than they do in North Rhine-Westphalia (14,309).

Table II/15

R&D personnel in the business enterprise (BE) sector

Parameter	in[3])	Total			Researchers	
		1991	1993	1994	1991	1993
		actual		estimate	actual	
Business enterprises	FTE	316,775	289,168	279,776	138,926	126,780
of which SMEs[1]):						
– in absolut terms	*FTE*	*56,374*	*53,782*	*53,499*	*27,827*	*26,732*
– percentage	%	*17.8*	*18.6*	*19.1*	*20.0*	*21.1*
IfG[2])	FTE	4,981	4,606	4,606	2,158	2,176
Total BE	**FTE**	**321,756**	**293,774**	**284,380**	**141,084**	**128,956**
– percentage of BE labour force	%	1.1	1.1	1.0	.	.
– percentage of R&D personnel/ researchers in all sectors[4])	%	62.4	61.8	.	58.6	56.1
of which:[5])						
old Länder (including West Berlin)						
– BE	FTE	282,772	268,427	.	117,112	.
of which SMEs[1]):						
– in absolute terms	*FTE*	*41,348*	*39,992*	.	*17,865*	.
– percentage	%	*14.6*	*14.9*	.	*15.3*	
– IfG[2])	FTE	4,062	3,315	.	1,682	.
Total	FTE	286,834	271,742	.	118,794	.
– percentage of BE labour force	%	1.2	1.2	.	.	.
– percentage of R&D personnel/ researchers in all sectors[4])	%	66	64	.	.	.
new Länder (including East Berlin)						
– BE	FTE	34,003	20,741	.	21,814	.
of which SMEs[1]):						
– in absolute terms	*FTE*	*15,025*	*13,790*	.	*9,962*	
– percentage	%	*44.2*	*66.5*	.	*45.7*	.
– IfG[2])	FTE	919	1,291	.	476	.
Total	FTE	34,922	22,032	.	22,290	.
– percentage of BE labour force	%	0.6	0.5	.	.	.
– percentage of R&D personnel/ researchers in all sectors[4])	%	42	43	.	.	.

[1]) SMEs: small and medium-sized enterprises.
[2]) IfG: Institutions for cooperative research and experimental development.
[3]) FTE: full-time equivalent.
[4]) Business enterprise, higher education and non-university sectors; estimates.
[5]) R&D laboratory concept.

Source: SV-Wissenschaftsstatistik GmbH, Federal Statistical Office and BMBF calculations

higher share than that relating to intramural R&D expenditure (4.1 %). This is an increase of almost one percentage point over 1992. After there had been a decline by 34.5 % from 1991 to 1992 and the personnel in business enterprise R&D in the new Länder had dropped by another 3.6 % from 1992 to 1993, the number of R&D personnel in that region of Germany now seems to have stabilised. Two factors have contributed to this development: First, detailed analyses show that there was an increase in R&D personnel in SMEs with less than 100 employees. This rise, however, was not high enough to compensate for the R&D manpower shed in SMEs in general. Second, there was only a moderate reduction in research personnel in large companies (with more than 500 employees).

The "structural difference" in terms of the proportion of SMEs in the total business enterprise sector that was identified with regard to financial resources also applies to R&D personnel. While in the old Länder in 1993 about 15 % of R&D personnel in the business enterprise sector worked in SMEs, it was about two-thirds in the new Länder.

The difference in R&D intensity (measured in terms of the share of R&D personnel in the total labour force employed in the business enterprise sector) between 1.2 % in the West and 0.5 % in the East confirms the differences between the business enterprise sectors in the old and the new Länder already identified in terms of intramural R&D expenditure.

9.2 Federal funding of research and development in the business enterprise sector

Scope

The Federal Government's expenditure on R&D in the business enterprise sector amounted to DM 4,675 billion in 1995 (budgeted). The breakdown was as follows:

- DM 1,455 million were accounted for by the Federal Ministry of Education, Science, Research and Development (BMBF),
- DM 702 million by the Federal Ministry of Economics (BMWi),
- DM 2,316 million by the Federal Ministry of Defence (BMVg), and
- DM 202 million by other governments departments.

R&D expenditure by the BMWi focused in particular on R&D programmes favouring SMEs (1995: DM 573 million) as well as on civil aircraft construction. Federal technology funding in the business enterprise sector that was not related to any departmental functions was provided by the BMBF.

Between 1992 and 1995 indirect and indirect specific technology funding by the Federal Government rose from DM 643.3 million to DM 743.8 million (cf. Tables II/16 and II/17).

R&D funding in the business enterprise sector as provided for in the BMBF budget was characterised by the following trends (cf. Table II/19):

- Direct project funding (projects which are usually assessed and decided upon on an individual basis) was reduced from DM 1,506 billion to DM 1,152 billion in the period from 1992 to 1995.
- From 1992 to 1995 funds allocated under the direct project funding scheme to financing key technologies in the business enterprise sector were mostly kept constant or were even stepped up: Appropriations were increased for computer science (+34 % to DM 26.8 million), microsystems (+61 % to DM 49 million), production engineering (+144 % to DM 50.1 million), biotechnology (+12 % to DM 40.5 million) and aeronautical research (+56 % to DM 75.3 million).
- Between 1992 and 1995 R&D funding in the business enterprise sector was reduced in the following areas: national funding of space research and space technology (–24 % to DM 136.8 million), fossil energy sources (–82 % to DM 8.4 million), renewable energies (–34 % to DM 79.5 million), nuclear energy research (–47 % to DM 46.4 million), decommissioning and disposal of nuclear facilities (–53 % to DM 100.7 million) and environmental technology (–42 % to DM 56.4 million).
- Direct project funding in the business enterprise sector accounted for about 32 % of total direct project funding by the BMBF intended to advance research and technology.

Supporting small and medium-sized enterprises is one focus of the Federal Government's programme of funding R&D in the business enterprise sector. The funds appropriated for this purpose in 1995 amounted to about DM 1.2 billion. DM 695 million were accounted for by indirect measures to support R&D in the business enterprise sector (cf. Table II/22 a). R&D expenditure by the Federal Ministry of Defence as well as other departmental research being disregarded in this context since they serve the purpose of generating results needed to fulfil specific departmental functions, SMEs received about 56 % of federal expenditure on R&D in the business enterprise sector. It should be noted that small and medium-sized enterprises with fewer than 500 employees spent only about 14 % (1994) of total intramural business enterprise R&D funds. It should also be taken into account that many Länder governments consider funding R&D in SMEs an important component of supporting the business enterprise sector on a regional basis for which they appropriate special funds. Finally, it should be pointed out that through the Kreditanstalt für Wiederaufbau (KfW; Reconstruction Loan Corporation) the Federal Government allocates more than DM 1 billion every year under innovation loan programmes to financing innovations in SMEs. Since ERP funds are used for this purpose these programmes have only relatively little impact on the budget.

Compared with the expenditure on R&D by industry itself, the funds appropriated for R&D in the business enterprise sector are relatively modest in all areas,

Table II/16

Indirect schemes for funding R&D in the business enterprise (BE) sector[1])

Scheme, responsible ministry in brackets	Funds/tax revenue shortfalls (DM million)							
	1989	1990	1991	1992	1993	1994	1995	1996[4])
Potential-oriented scheme								
– Grant towards R&D payroll cost (BMWi) (as from 1992 R&D personnel funding in the new Länder)	29.3	5.2	1.9	47.9	91.8	67.1	109.6	130.0
– Funding for additional R&D personnel (BMBF)	81.5	59.9	30.3	25.9	21.1	18.7	17.5	16.0
– R&D investment allowance (tax-related measure pursuant to sect. 4 of the Investment Grant Act)[2])	449.3	470.9	178.8	–	–	–	–	–
– Special R&D depreciation (tax-related measure pursuant to sect. 82d of the Ordinance Regulating the Income Tax Law)[2])[3])	200.0	200.0	200.0	–	–	–	–	–
Schemes to support cooperation between the BE sector and science								
– Industrial cooperative research (BMWi)	106.9	112.2	199.8	198.1	169.6	169.9	169.9	170.0
– Contract research and development (BMBF)	28.0	22.0	31.7	44.3	70.3	60.8	85.5	53.0
– Technology transfer and research cooperation (BMBF)	21.9	17.9	15.7	17.8	14.4	52.9	100.0	134.8
– Technology transfer pilot projects (including patent inspection offices) (BMWi)	0.8	6.5	13.5	27.9	37.4	40.6	34.4	30.0
Funding of innovation (BMWi)	–	–	0.2	8.4	50.6	80.0	82.0	85.0
Funding of new technology-based firms (BMBF)	53.5	40.2	45.9	77.0	81.7	67.2	64.1	62.9
R&D loans for small businesses to encourage the application of new technologies	–	–	–	–	–	2.2	5.9	9.3
Pilot scheme to support information retrieval from databases (MIKUM)	–	–	2.8	8.1	6.2	4.7	2.7	3.9
Total	**971.2**	**934.8**	**720.6**	**455.4**	**543.1**	**564.1**	**671.6**	**694.9**

[1]) Including special funds for "Aufbauhilfe Ost" (Development assistance for the new Länder).
[2]) Tax revenue shortfalls of Federal, Länder and local governments.
[3]) Estimated; in some cases adjusted estimates.
[4]) Budget.
Source: BMBF

with the exception of aerospace technology. In most cases they are not high enough to change cost relations to such an extent as to influence significantly the allocation of R&D funds by the sector itself.

Rationale

In a market economy system developing new products and process technologies is one of the basic functions of private companies; high technological performance calls for intensive national and international competition in the field of innovation. The government's responsibility is primarily to create a general setting conducive to innovation as well as an efficient and adaptable scientific and technological infrastructure. Beyond this, grants to the business enterprise sector are needed to perform research and development if and when there are special reasons to do so:

- In the case of modern high technologies basic research and applied research tend to merge. The development of high technologies greatly depends on science. Innovations are not the result of a linear process leading from basic research to application-oriented research to the development of prototypes. They rather tend to emerge as a result of recurrent processes where even at late development stages close cooperation with basic research is needed. Conversely, basic research is often fertilised by applied research. Technologies have a history in which scientific knowledge and technological know-how need to be developed on

Table II/17

Indirect specific funding of R&D in the business enterprise (BE) sector by the BMBF[1])

Scheme	Funds (DM million)					
	1991	1992	1993	1994	1995	1996[3])
Production engineering (CAD/CAM, robotics, CIM)	63.0	92.6	43.4	18.7	5.3	7.0
Information technology (microperipherals, microsystems)	22.1	32.6	21.7	12.7	1.7	2.0
Bioprocess engineering[2])	7.3	24.8	26.2	21.8	29.3	20.0
250 MW-Wind	8.0	16.4	24.8	27.3	32.0	34.0
1,000 Roofs photovoltaics programme	3.0	20.7	30.8	10.0	1.4	–
"Solar thermal power 2000" programme	–	–	–	–	3.4	5.0
Total	**103.4**	**187.1**	**146.9**	**90.5**	**73.1**	**68.0**

[1]) Including special funds for "Aufbauhilfe Ost" (Development assistance for the new Länder).
[2]) Including research scholarships.
[3]) Budget.

Source: BMBF

Rounding error

Table II/18

Funding of R&D by the BMBF in 1995[1]) by function, funding area/funding priority
– direct project funding*) –

– profile review –

Function Funding area/funding priority	Total DM '000	Share of BE	
		DM '000	%
1 Knowledge-oriented and cross-programme basic research	**132,428**	**–**	**–**
of which			
B Large-scale equipment for basic research	132,428	–	–
2 Research and development to provide for the future	**935,069**	**58,571**	**6.26**
of which			
C1 Marine research	84,119	1,502	1.79
C3 Polar research	7,035	521	7.41
F1 Ecological research	81,914	1,512	1.85
F7 Climate and atmospheric research	83,640	12,201	14.59
G Research and development in the service of health	194,486	2,816	1.45
H Research and development to improve working conditions	64,994	24,973	38.42
O1 Geosciences (especially deep drillings)	51,900	–	–
P2 Building research and technology	25,387	1,190	4.69
S1 Vocational training research	33,073	3,211	9.71
O2 Other educational research	60,749	1,429	2.35
V Humanities	44,571	–	–
W1 Cross-disciplinary activities (including technology impact assessment)	203,201	9,216	4.54

cont. Table II/18

Function Funding area/funding priority	Total DM '000	Share of BE DM '000	Share of BE %
3 Support of technology and innovation	**2,365,505**	**1,093,179**	**46.21**
of which			
C2 Marine technology	35,521	26,259	73.93
D1 National funding of space research and space technology	320,787	136,815	42.65
E1 Coal and other fossil energy sources	25,905	8,356	32.26
E2 Renewable energies and energy conservation	177,899	79,452	44.66
E3 Nuclear energy research (excluding decommissioning of nuclear facilities)	85,905	46,428	54.05
E4 Decommissioning of nuclear facilities	228,111	100,732	44.16
F2 Environmental technologies	150,470	56,438	37.51
I1 Computer science	93,688	26,823	28.63
I2 Basic information technologies	318,625	143,563	45.06
I3 Application of microsystems (including microelectronics, microperipherals)	102,180	49,332	48.28
I4 Production engineering	95,441	50,054	52.44
K Biotechnology	148,569	40,456	27.23
L1 Materials research	129,637	74,657	57.59
L2 Physical and chemical technologies	195,137	54,818	28.09
M Aeronautical research and hypersonic technology	98,811	75,314	76.22
N Research and technology for ground transport	134,072	120,485	89.87
O2 Raw material supplies	–	–	–
U Specialised information	24,747	3,197	12.92
4 University construction and mainly university-related special programmes	**134,706**	**–**	**–**
of which			
A6 Mainly university-related special programmes	134,706	–	–
Total*)	**3,567,706**	**1,151,749**	**32.28**

*) Excluding direct project funding under "Other educational expenditure not relevant to R&D". In 1995 direct project funding by the BMBF totalled DM 4,185,161,000.

1) Provisional actual data including funds controlled and allocated by the BMBF under departmental budget 60.

Source: BMBF — Rounding error

a complementary and interactive basis and institutional barriers overcome (learning curve effect).

It is the objective of technology funding to open up optimal opportunities in Germany for scientific and technical developments with a potential for broad-based application (e.g. photonics, molecular electronics, nanotechnology). To this end, research capacities, including those of large companies, need to be involved. Research funding also helps broaden the knowledge base on which companies perform short-term research and development activities. Another – and not the least – contributing factor is that young researchers gather working experience at the cutting edge of scientific and technological progress. Taking into account the financial and immaterial commitment and associated justified expectations of profit, the results of research funding should be accessible for broadest possible use by third parties.

To improve the implementation of knowledge generated in this process the issue of greater orientation of funded projects to later applications and uses has become more important in recent years. This means that perspectives of industrial implementation by business enterprises enter more and more into project selection and management.

When it supports key technologies in the business enterprise sector the Federal Government complies with the principle of subsidiarity. Only if the companies themselves cannot develop such technologies satisfactorily or not at all or if they cannot do so quickly enough, will the requirements for government research grants be considered met. But even then the Federal Government will basi-

Table II/19

Direct R&D project funding by the BMBF*) in the business enterprise (BE) sector from 1991 to 1995[1])
by function, funding area and funding priority
– profile review –

Function Funding area/funding priority	Funds (DM '000)			
	1992	1993	1994	1995[2])
1 Knowledge-oriented and cross-programme basic research	–	–	–	–
2 Research and development to provide for the future	**87,647**	**57,324**	**60,769**	**58,571**
of which				
C1 Marine research	10,583	6,791	1,437	1,502
C3 Polar research	366	387	824	521
F1 Ecological research	2,068	1,192	912	1,512
F7 Climate and atmospheric research	11,687	4,052	14,314	12,201
G Research and development in the service of health	3,116	1,798	2,428	2,816
H Research and development to improve working conditions	38,578	27,156	24,849	24,973
O1 Geosciences (especially deep drillings)	79	62	38	–
P2 Building research and technology	4,799	2,764	2,965	1,190
S1 Vocational training research	4,048	3,152	3,406	3,211
S2 Other educational research	2,006	1,230	1,385	1,429
W1 Cross-disciplinary activities (including technology impact assessment)	10,317	8,739	8,212	9,216
3 Support of technology and innovation	**1,418,503**	**1,250,149**	**1,187,183**	**1,093,178**
of which				
C2 Marine technology	26,873	29,182	30,555	26,259
D1 National funding of space research and space technology	179,798	189,719	203,732	136,815
E1 Coal and other fossil energy sources	47,303	22,309	12,064	8,356
E2 Renewable energies and energy conservation	119,843	103,131	98,110	79,452
E3 Nuclear energy research (excluding decommissioning of nuclear facilities)	88,145	73,073	55,830	46,428
E4 Decommissioning of nuclear facilities	212,657	158,910	96,466	100,732
F2 Environmental technologies	97,119	64,801	67,274	56,438
I1 Computer science	20,080	16,187	21,395	26,823
I2 Basic information technologies	195,979	171,259	179,233	143,563
I3 Application of microsystems (including microelectronics, microperipherals)	30,558	39,637	39,522	49,332
I4 Production engineering	20,475	40,409	44,368	50,054
K Biotechnology	36,067	18,714	24,398	40,456
L1 Materials research	77,651	76,524	69,048	74,657
L2 Physical and chemical technologies	58,865	46,443	43,268	54,818
M Aeronautical research and hypersonic technology	48,131	44,173	50,303	75,314
N Research and technology for ground transport	152,751	151,745	148,419	120,485
O2 Raw material supplies	459	30	–	–
U Specialised information	5,747	3,903	3,200	3,197
4 University construction and mainly university-related special programmes	–	–	–	–
of which				
A6 Mainly university-related special programmes	–	–	–	–
Total*)	**1,506,149**	**1,307,472**	**1,247,951**	**1,151,749**

*) Excluding direct project funding under "Other educational expenditure not relevant to R&D". Direct project funding by the BMBF totalled DM 1,508,225,000 in 1992, DM 1,310,293,000 in 1993, DM 1,251,341,000 in 1994 and DM 1,154,868,000 in 1995.
[1]) Including funds controlled and allocated by the BMBF under departmental budget 60.
[2]) Provisional actual data as of 31 December 1995.
Source: BMBF

Rounding error

cally limit itself to providing help for self-help. The objective of funding is to support the development of technologies with a view to implementing them and not to support individual companies. This approach is reflected, above all, in the BMBF's specialised technology programmes.

- New technological developments are increasingly produced at the boundaries of traditional disciplines and entrepreneurial core competences. Often they are so complex that a single business enterprise cannot provide all the know-how resources required to cope with the tasks in hand. Especially in those cases where companies need to combine highly different technology areas, at the same time involving public research institutions and SMEs (e.g. microsystems, versatile use of new materials), high risks and communication problems obstruct the further development of technologies and their applications.

  Acting as a facilitator, the Federal Government supports the process of innovation by funding such projects. The joint participation of several companies and research institutions in research networks helps make more efficient use of scarce research capacities, accelerate the technology transfer between science and industry, produce synergy effects and reduce the selectivity of funding.

  To be implemented complex technological systems often require government decisions on infrastructure, e.g. when the thrust and objectives of work in government research institutions are defined; they also need adequate basic conditions and government participation in defining norms and standards. As a provider of knowledge, technology policy facilitates infrastructural innovations and the creation of optimal basic conditions in newly emerging markets. A case in point is mobile radio; research and technology policy played a central role in the development of the highly successful GSM standard. Another example is the development of traffic guidance systems (Prometheus).

  To support research networks is also the idea underlying the European EUREKA research initiative. EUREKA is not a research programme focusing on a clear-cut theme (this is why it is called an initiative), but rather provides an open framework for European cooperative projects. Participants do not respond to calls for proposals, but define the themes, partners, scope and type of cooperation of their own accord. Projects are financed at the national level, i.e. separately in each participating country. In Germany participation in EUREKA does not automatically entitle a company to a government grant (cf. Part V, Section 1.2.1).

- In the area of preventive research and research into future needs (ecological research, development of environmental technologies, climate and atmospheric research, research and development in the service of health, research and development to improve working conditions, building research and technology, research and technology for the conservation of architectural heritage as well as generic activities such as technology impact assessment) the business enterprise sector with its research capacities is an indispensable partner when it comes to the quick provision and further development of the technological basis and the development of orientational knowledge. Supporting the development of environmental technology in particular serves the objective of demonstrating the feasibility of certain technologies designed to reduce and/or prevent environmental pollution. In many areas companies do not have an economic interest in further developing a state-of-the-art technology under their own steam. Financial support helps prepare and assist the formulation and implementation of environmental policy measures.

- Due to their focus on the marketplace and their flexibility SMEs are a driver of economic development. But in the innovation process they labour under size-specific disadvantages which prevent them from taking up innovation activities. These include a lack of opportunity to spread the risk, minimum company size required for R&D projects, fewer capacities to acquire and process information as well as harder access to borrowed capital and equity. Empirical studies have confirmed that engaging in research and innovation activities is impeded by threshold effects. There are fewer SMEs than large companies that perform research and development. But when SMEs engage in research they have a higher research intensity measured against turnover. In the innovation competition SMEs can occupy widely varying positions which range from the role of a technology pioneer to that of a trailblazer in the dissemination of new technologies in the national economy to that of a user who buys in new technologies in the form of subassemblies or as complete equipment. This is why depending on the funding objective the Federal Government has a wide range of differentiated tools to support SMEs (Table II/22 a shows a compilation of the Federal Government's most important indirect funding schemes).

- To fulfil its other functions the Federal Government also acts as a buyer of research services and technology developments from the business enterprise sector. Payments to this sector for the development of new technologies for infrastructure (e.g. environmental measuring techniques), in the area of defence research as well as to accomplish tasks under long-term government research programmes (space research, marine and polar research) are registered in statistics as government R&D funds paid to the business enterprise sector.

Successful research and development is a necessary but not a sufficient condition for successful participation in the innovation competition. Government funding of R&D in the business enterprise sector is intended to increase the pool of ideas which industry taps to develop its innovative strategies, while at the same time it is meant to help remove barriers to communication and cooperation between the players in the innovation system. Many of the latest results of economic research emphasise the great macroeco-

Table II/20

Federal funding of civil research and development in the business enterprise (BE) sector[1]) by ministry and number of recipient businesses/agencies

Ministry/scheme	1993		1994	
	Recipient businesses/ agencies	Funds	Recipient businesses/ agencies	Funds
	Number	DM million	Number	DM million
BMBF				
– Direct project funding	1,548	1,304.1	1,727	1,234.0
– Microperipherals/microsystems (indirect specific scheme)	248	21.7	146	12.7
– Production engineering (indirect specific scheme)	450	43.4	299	18.7
– Biotechnology (indirect specific scheme)	144	23.0	159	25.2
– 250 MW Wind	252	18.8	312	20.1
– 1,000 Roofs photovoltaics progamme	2	6.4	2	2.3
– Solar thermal power 2000	.	0.0	2	0.9
– Funding of additional R&D personnel	717	18.0	775	17.5
– Contract research and development	776	69.8	894	59.2
– New technology-based firms (NTBFs)	224	80.0	187	67.2
– Research cooperation between BE and science	409	14.0	988	49.9
– R&D loans	.	0.0	.	2.2
Total BMBF	4,770	1,599.2	5,491	1,509.9
BMWi				
– Industrial cooperative research	619	169.6	634	169.9
– R&D-personnel funding in the new Länder	1,417	91.8	1,576	67.1
– Funding of innovation	282	50.6	431	80.0
– Technology transfer and specialised information	97	49.5	100	55.0
– Grants towards the development of civil aircraft	8	411.3	7	287.7
– Projects funding at industry-related research institutions	222	99.3	254	149.5
– Funding of design	–	–	185	2.0
Total BMWi	2,645	872.1	3,187	811.2
Total	**7,415**	**2,471.3**	**8,678**	**2,321.1**

[1]) Including special funds for "Aufbauhilfe Ost" (Development assistance for the new Länder); defintion of BE sector differs from that in Table II/21.

Source: BMWi, BMBF

Table II/21

Federal R&D funding in the business enterprise (BE) sector including research-related tax revenue shortfalls of Länder and local governments from 1974 to 1994

Year	Total expenditure[1])	of which						Tax revenue shortfalls[2])	Total funding
		BMBF		BMWi		BMVg			
	DM million	DM million	%	DM million	%	DM million	%	DM million	
1974	2,913	1,288	44	300	10	1,283	44	358	3,271
1975	3,161	1,507	48	285	9	1,319	42	149	3,310
1976	3,049	1,278	42	240	8	1,462	48	106	3,155
1977	3,110	1,448	47	139	4	1,449	47	153	3,263
1978	3,491	1,673	48	173	5	1,559	45	139	3,630
1979	4,542	2,169	48	610	13	1,657	36	169	4,711
1980	4,616	2,200	48	798	17	1,496	32	191	4,807
1981	4,629	2,330	50	852	18	1,355	29	289	4,918
1982	5,628	3,251	58	816	14	1,458	26	283	5,911
1983	5,068	2,653	52	716	14	1,595	31	429	5,497
1984	5,155	2,617	51	703	14	1,729	34	630	5,785
1985	5,770	2,540	44	897	16	2,235	39	615	6,385
1986	5,403	2,232	41	843	16	2,237	41	633	6,036
1987	5,057	1,989	39	638	13	2,331	46	658	5,715
1988	5,038	1,988	39	621	12	2,321	46	695	5,733
1989	5,181	1,799	35	650	13	2,626	51	648	5,829
1990	5,423	1,706	31	803	15	2,782	51	671	6,094
1991	5,463	1,653	30	924	17	2,747	50	379	5,842
1992	5,560	1,741	31	831	15	2,637	47	–	5,560
1993	4,739	1,597	34	847	18	2,101	44	–	4,739
1994	4,599	1,482	32	799	17	2,111	46	–	4,599

[1]) Including funds received by business enterprises abroad.
[2]) R&D investment allowance (sect. 4 of the Investment Grand Act) and special R&D depreciations (sect. 82d of Ordinance Regulating the Income Tax Law), tax revenue shortfalls by Federal, Länder and local governments (revised data).
Source: BMBF — Rounding error

nomic benefit of human capital-intensive activities, the relevance of historical events to explain technological development processes and resulting differences in growth at the international level. A number of recent econometric studies have shown that the macroeconomic benefit of research and development is much higher (sometimes 50 % to 100 %) than private-enterprise income. By funding R&D in the business enterprise sector the Federal Government lives up to its responsibility to ensure the development and broad-based application of new (technological) knowledge in Germany.

Funding of R&D in the business enterprise sector of the new Länder

Initial situation and development

The structural change initiated in the new Länder in the wake of German unification has also affected research and development in the business enterprise sector and resulted in a sizeable reduction of industry-related R&D capacities. R&D is a crucial prerequisite for competitive companies and safe jobs. Only if East German businesses are able to establish their presence in the markets with innovative and competitive products, will it be possible to start a self-feeding recovery in that part of Germany as well.

Building up and maintaining efficient R&D in the East German business enterprise sector is still difficult and inconsistent. On the one hand, redressing economic imbalances and overcoming the lack of competitiveness and innovative capacity called for a radical restructuring of the business enterprise sector, a process that had to be accompanied by a reorientation of intramural R&D. On the other hand, there was the risk that due to short-term financial difficulties and temporarily empty order books, R&D capacities that were worth keeping and vital for future competitiveness would also be discarded in this restructuring and adaptation process.

After severe shrinkage, promising signs of a consolidation of R&D can now be detected in the business enterprise sector of the new Länder. Manpower re-

Table II/22a

Federal Government schemes to fund research and development in small and medium-sized enterprises[1])

– DM million –

Ministry/scheme	1992	1993	1994	1995
BMBF				
1 Project funding under specialised programmes	259.2	300.0	300.0	300.0
(of which:				
cooperative industrial research project funding under specialised programmes)	(25.9)	(10.3)	(8.3)	(6.3)
2 Indirect specific schemes				
Production engineering (CAD/CAM, robotics, CIM)	83.2	39.1	16.8	4.8
Information technology (microperipherals, microsystems)	25.8	17.3	10.1	1.3
Bioprocess engineering	14.5	18.4	20.2	17.8
250 MW Wind	10.6	18.8	21.5	26.2
1,000 Roofs photovoltaics programme	2.9	6.4	2.3	0.0
Solar thermal power	–	–	0.9	2.7
3 New technology-based firms	69.7	79.0	67.2	61.3
4 R&D credit scheme for SMEs to encourage the application of new technologies	–	–	2.2	5.9
5 Funding of additional R&D personnel	22.4	18.0	17.5	16.2
6 Contract research and development	43.6	69.8	59.2	85.5
7 Research cooperation between the business enterprise sector and science	12.5	14.0	49.9	93.0
8 Information and consultancy centres	26.3	15.3	22.1	20.0
9 Technology transfer and specialised information	8.1	6.2	4.7	2.7
Total BMBF	578.8	602.3	594.6	637.4
BMWi				
1 Industrial cooperative research	198.1	169.6	169.9	169.9
2 Grant towards R&D payroll cost	47.9	91.8	67.1	109.6
3 Funding and support of innovation	8.4	50.6	80.0	82.0
4 Project funding in industry-related research institutions	102.7	99.3	149.5	175.4
5 Technology transfer pilot projects (including patent inspection offices)	28.1	37.4	40.6	34.4
6 Funding of design	–	–	2.0	2.0
Total BMWi	385.2	448.7	509.1	573.3
Total	**964.0**	**1051.0**	**1103.7**	**1210.7**

[1]) Includes only appropriations to small and medium-sized enterprises, including special funds for "Aufbauhilfe Ost" (Development assistance for the new Länder).
Estimated in some cases.

Source: BMBF

duction has come to a halt. Small and medium-sized enterprises in particular have stabilised their research and development activities and are beginning to step up the funds needed for R&D. West German companies are increasingly performing R&D in the new Länder. The extraordinary commitment of the Federal Government, involving extensive government funding schemes, had a stabilising effect on the entire research and development potential of the business enterprise sector in the new Länder.

Currently about one quarter to one-third of the business enterprises in the new Länder – that is about 2,500 companies of which approximately 900 have fewer than 20 employees – are involved in R&D activities. The focus of these activities – in contrast to the West German situation – is formed by SMEs which employ about 70 % of business enterprise R&D personnel.

The challenge for the future is for the business enterprise sector, the governments of the new Länder as well as the Federal Government – each within their responsibilities – to continue to push the development of efficient R&D capacities in the industrial sector of the new Länder. An even stronger commitment of the business enterprise sector will be of crucial importance since in the medium and long term only industry itself can maintain and employ efficient R&D capacities. It is not least the companies in the old Länder which are also called upon to increase their commitment.

Table II/22b

Federal Government schemes to fund research and development in the business enterprise sector in the new Länder

– DM million –

Ministry/scheme	1992	1993	1994	1995
BMBF				
1 Project funding under specialised programmes	133.4	183.4	192.4	166.0
2 Research cooperation (share of new Länder)	–	0.6	13.4	32.3
3 Project funding in industry-related institutions[1])	92.4	–	–	–
4 New technology-based firms	43.2	55.3	42.1	37.6
5 Establishment and expansion of technology parks	9.7	7.0	1.7	–
6 Contract research and development	33.5	67.3	83.7	85.4
7 Funding of additional R&D personnel	19.3	19.8	18.2	16.5
8 Product engineering (indirect specific CIM funding)	18.0	32.6	18.6	5.4
9 Innovation and consultancy centres	7.4	5.0	18.0	2.3
10 Pilot scheme on innovation consultancy centres at chambers of industry and commerce	0.4	0.3	0.3	0.5
Total BMBF	357.3	371.3	388.4	346.0
BMWi				
1 Research cooperation (share of new Länder)	67.1	45.8	39.6	35.3
2 R&D personnel funding in the new Länder	47.9	91.8	67.1	109.6
3 Funding and support of innovation	8.4	50.6	80.0	82.0
4 Technology transfer	16.5	27.8	31.6	25.0
5 Industry-related specialised information	6.6	4.0	4.0	4.1
6 Funding of design	–	–	1.8	1.8
7 Project funding in industry-related research institutions[1]) pre-competitive R&D	102.7	99.3	149.5	175.4
Total BMWi	249.2	319.3	373.6	433.2
Total	**606.5**	**690.6**	**762.0**	**779.2**

[1]) 1992 appropriations under departmental budget 60 ("Aufbauhilfe Ost" (Development assistance for the new Länder)).

Source: BMBF

Rounding error

Federal Government programmes to promote and fund R&D in the business enterprise sector of the new Länder (cf. Figure II/11)

Top priority has been given to establishing and strengthening the technological competitiveness of East German companies and assisting the reorientation of industry-related R&D capacities. Under its specialised programmes the BMBF supports companies and industry-related research institutions in the new Länder by funding R&D projects, especially in the areas of environmental technology, production engineering, renewable energies and energy conservation, basic information technologies, space technology, materials research as well as ground transport. The funding rate for recipients in the new Länder is 10 % higher than in the West, and there are numerous provisions to speed up, simplify and facilitate applying for, and appropriating, grants.

Restructuring companies that were primarily engaged in R&D activities, especially the Research GmbHs (limited liability companies), went hand in hand with early supportive measures. These included in particular – in continuation of the joint scheme "Aufschwung Ost" (Upswing East) – the programme for "Pre-competitive industrial research and structural change in industry" by the Federal Ministry of Economics (BMWi) for which a total of DM 650 million had been appropriated by late 1995.

By supporting *new technology-based firms (NTBFs)* the Federal Government contributed to building up innovative small and medium-sized enterprises. A BMBF pilot scheme helped finance NTBFs in the new Länder.

BMBF and BMWi took, and are taking, specific measures to strengthen *innovative small and medium-sized enterprises.* The BMWi scheme *"Grants towards R&D payroll cost in the East"* aims to restructure and strengthen the innovative potential of SMEs. The BMBF's *funding of additional R&D personnel* supported the development and expansion of R&D capacities in SMEs in the new Länder.

The BMBF had, and still has, two versions of its scheme for supporting contract research and development *(Contract research East* and *Contract research East/West).* With its *scheme for assisting innovation* the BMWi supports the development of new innovative products and processes in SMEs in the new Länder. The technical and economic risk associated with such development activities is reduced by grants (of up to 35 %).

An important pillar of the BMBF's scheme for supporting SMEs is the nation-wide programme *"Support of research cooperation in small and medium-sized enterprises"* which was launched in September 1993 and to which an increasing number of businesses have responded since 1994.

With its scheme for funding cooperative industrial research which focuses on cooperative research at the sectoral level, the BMWi supports pre-competitive, application-oriented basic research driven by industrial demand. Funds have been allocated to various research projects which were identified as tasks of mutual interest by companies that have formed research associations. From the time of unification until 1995 about DM 260 million were appropriated for involving business enterprises and research institutions in the new Länder in cooperative industrial research activities. This sum accounted for 28.6 % of total funds.

By developing an *R&D-supporting infrastructure* the BMWi and BMBF create a suitable general setting for the innovation process. Agencies for Technology Transfer and Innovation Assistance provide technical and administrative help to set up and expand SMEs and assist them in developing and implementing innovative products and processes. The agencies' activities are complemented by sector-specific or technology-oriented transfer centres which act as clearing houses for specialised technical know-how. An important approach to supporting the transfer of technology, especially to SMEs in the new Länder, is the exemplary temporary funding by the BMBF of so-called Centres for Information and Consultancy in new technology areas where companies can gather hands-on experience with key technologies.

The know-how and experience of companies that are world market leaders in research and the application of new technologies are also of great benefit to other businesses, especially smaller, highly innovative firms. This is why in early 1992 the BMWi launched the scheme *"Technology-oriented visiting and information programmes"* which aims to enhance the continuous transfer of technical know-how between businesses. From the moment the scheme was launched leading technology companies have shown great willingness to demonstrate the application of modern technology and technological strategies on their own premises.

All in all, the Federal Government's schemes to fund R&D in the business enterprise sector in the new Länder are successful. About 80 % to 90 % of R&D-performing companies in East Germany take advantage of these programmes. The Federal Government is thus making a substantial contribution to renewing the structure of the business enterprise sector in the Eastern part of Germany. In 1995 alone more than DM 755 million was appropriated for this purpose (see Table II/22 b). In 1996, too, the BMBF and BMWi will continue to support the development of efficient research capabilities in the business enterprise sector in East Germany. The success of these efforts, however, will very much depend on whether industry will increase its own R&D commitment as well. Federal R&D funding schemes are complemented by specific programmes of Länder governments as well as other federal tax-related and regional measures conducive to investment, such as a capital investment bonus, special write-offs and investment grants paid under the joint scheme "Improvement of regional economic structures". With these general investment aids the Federal Government also supports investment in the R&D sector, thus rounding off its range of funding schemes.

Figure II/11

Federal Government schemes to fund R&D in the business enterprise (BE) sector in the new Länder

Objective	Scheme	1995 actual DM million
To develop and improve technological competitiveness	Project funding under BMBF specialised programmes	166.0
	Pre-competitive industrial research, BMWi	175.4
	Industrial cooperative research	35.2
To fund new technology-based firms	New technology-based firms, BMBF (NTBFs)	37.6
To develop and strengthen innovative SMEs	R&D personnel funding in the new Länder, BMWi (PFO)	109.6
	Funding of additional R&D personnel in the new Länder, BMBF	16.5
	Contract research and development, BMBF	85.4
	Innovation funding scheme, BMWI	82.0
	Research cooperation, BMBF	32.3
	Production engineering – indirect specific funding – (CIM)	5.4
To develop an infrastructure supporting R&D	Agencies for technology transfer and innovation funding, BMWi	25.0
	Innovation consultancy at chambers of industry and commerce, BMBF	0.5
	Centres for information and consultancy, BMBF	2.3
	Industry-related specialised information, BMWI	3.8
Total		777.0

Source: BMBF

BMBF, BuFo '96

9.3 Germany's technological performance

Internationalisation of research and development

In Germany – as in other industrialised countries – the internationalisation of research and development in multinational companies has progressed continuously and reached a relatively advanced level. But nevertheless R&D and patent data show that in almost all major industrialised countries the greater part of research and development is still performed in the home countries of the companies concerned. In contrast, businesses in smaller industrialised countries and also in the UK have reached an above-average level of internationalisation.

German companies performing R&D abroad

Like direct investment statistics, a complete survey of the R&D activities of German companies holding participating interests abroad is not yet available. But some countries (USA, UK, France, Japan) have provided information on the R&D expenditure by companies in which foreigners hold participating interests. Based on these data the R&D expenditure by German companies abroad in 1993 can be estimated at about 15 % of the R&D expenditure of the business enterprise sector in Germany (based on purchasing power parity). In the chemical and pharmaceutical industries which have the highest level of internationalisation this figure is just under 30 %. According to various analyses, the percentage of patent applications filed by German companies where the invention was made outside Germany was between 11 % (European Patent Office) and 15 % (US Patent Office) in the late 1980s. Patent data thus provide additional proof of the fact that the share of research in German companies based abroad was correctly estimated to be around 15 %.

Foreign companies performing R&D in Germany

To estimate the R&D expenditure by foreign companies in Germany SV-Wissenschaftsstatistik GmbH, in

Table II/23

Technology trends in the late 1980s and early 1990s in R&D-intensive areas (applications filed with the European Patent Office)

Technology area	1988 to 1993 %	Mean change 1988 to 1993 – % p.a. –
Total technology	100.0	– 1.8
R&D-intensive technology	61.2	– 1.6
high technology	26.3	– 0.5
of which government-protected	0.6	– 5.0
other high technology	25.7	– 0.4
Advanced technology	34.8	– 2.3
Other technology	38.8	– 2.1
R&D-intensive technology	61.2	– 1.6
Pharmaceuticals	9.3	– 3.8
Agrochemistry	0.5	– 1.2
Turbines, power plants	0.6	– 5.3
Business machines, computers	5.8	1.8
Communications, electronics	7.5	4.1
Advanced electronics	2.1	2.2
Aerospace technology	0.2	1.1
Specialty chemicals	2.5	– 0.2
Plastics, resins	3.3	– 6.3
Construction machinery, handling	1.8	0.2
Metal working	2.7	– 2.9
Special industry machinery	1.8	– 0.4
Service machines	2.6	– 0.1
Electrical circuits	1.7	– 0.7
Home electronics	2.5	0.3
Automotive technology	3.4	– 1.8
Rail vehicle technology	0.4	4.8
Medical instruments	12.6	– 1.4

Source: "Germany's Technological Performance", background-material to the report on behalf of the Federal Ministry of Education, Science, Research and Technology, study by the Institute for Systems and Innovation Research (ISI) of the Fraunhofer Society, Bonn 1996, page 9

a special analysis of their regular annual survey of the 500 most research-intensive companies, identified majority interest held either by Germans or by foreigners in 1993. In their study they covered 80 % of the domestic R&D personnel of the companies and 85 % of total R&D expenditure. The analysis shows that the subsidiaries of foreign companies in Germany spent at least DM 7.8 billion on research and development and employed a minimum of 34,600 persons (on a full-time equivalent basis) for R&D. According to the results of the special evaluation of the survey by SV-Wissenschaftsstatistik GmbH foreign companies contributed just under 16 % to total R&D expenditure in the domestic business enterprise sector in 1991. In the USA and France the corresponding figure was almost 15 %, in the UK 26 % and in Japan 5 %.

Slightly more than two-thirds of the R&D personnel of companies with a foreign majority interest in the manufacturing sector work in the electrical engineering and road vehicle construction industries. In 1993 foreign companies performed their R&D activities almost exclusively in the old Länder. Less than 1 % of their research personnel worked in the new Länder where large German companies also made only a sub-average contribution to the total R&D expenditure in the business enterprise sector.

In international comparison Germany is an attractive country for performing R&D. About one quarter of all R&D expenditure by US companies abroad is accounted for by Germany (cf. Part I, Figure I/1). From the US perspective Germany has been leading the list of research locations abroad for quite some time. Germany has the highest percentage of manufacturing Japanese subsidiaries performing their own R&D. For Japanese companies which have established 17 research centres not related to production Germany is the second most important location in Europe after the UK.

Perspectives

As in other countries, the percentage of R&D performed by foreign companies in Germany is in most cases closely linked with production. R&D activities abroad are largely the result of an internationalisation of production. This is why, in the wake of a dynamic growth in investment abroad, the R&D potential of German companies abroad is expected to grow faster than that of foreign companies in Germany.

So far basic research – at least basic research in the core areas of the corporate production range – has often been located close to group headquarters. It is only in technology areas developing more recently which depend strongly on science that research has been decentralised.

For the time being it is an open question how globalisation will change the traditional priorities of research and development in Germany. In technological competition companies are under great pressure to increase the efficiency of their research by shortening product life cycles, eliminating the duplication of research as well as taking advantage of economies of scale offered by research and development centres. There is a trend towards setting up regional corporate centres of excellence that are responsible for R&D, production and sales. A country can improve its technological performance when multinational companies convert their subsidiaries into such centres of excellence. Crucial factors apart from R&D capacities and skills are the market and production potentials offered by a particular location.

Traditionally, R&D companies have strong historical ties with their locations. Germany is competing with other countries especially when it comes to developing new R&D capacities or reorganising R&D activities distributed world-wide on the basis of a division of labour. In such cases the decisions taken by multinational companies in favour of or against Germany are a yardstick for the attraction of this country as a research location.

Patent account

> The following analyses are based on the list of research-intensive commodities prepared by the Fraunhofer Institute for Systems and Innovation Research (ISI), Karlsruhe, which breaks down R&D-intensive commodities into high-technology goods and advanced-technology products. High technology comprises product groups with an average R&D share in turnover of more than 8.5 %. Advanced technology covers product groups whose R&D share in turnover is between 3.5 % and 8.5 %.

After the high increase in patent applications world-wide in the late 1980s there was a major turning point in the early 1990s. Compared with 1988, the first year under review, the number of total applications had dropped by almost 2 % by 1993. This period coincides with the phase of world-wide economic recession which in almost all economies of OECD member states resulted in negative economic growth or, at best, in stagnation. Apparently this also affected technological development and innovative activities. There are clear differences in the development of individual technology areas. In a small group of technology fields a growing innovative dynamism has evolved. These areas include rail vehicle construction, microelectronics and its applications as well as aerospace technology. On the other hand, almost all areas of the mechanical engineering and chemical industries are affected by a decline (cf. Table II/23).

Behind the USA and Japan Germany is the third largest technology producer world-wide and in Europe it is even by far the largest one. The annual numbers of patents applied for in at least two of the triad regions USA, Japan and the EU are almost three times higher than those of France and the UK. Compared with other countries the time series shows only minor fluctuations. Application figures declined slightly around 1982 and then rose again until 1987 to reach the level of the early 1980s of about 6,000 patents per year. Since then a continuous decrease was reported to about 5,000 patents by 1993. Since the early 1990s the number of technological innovations

Figure II/12

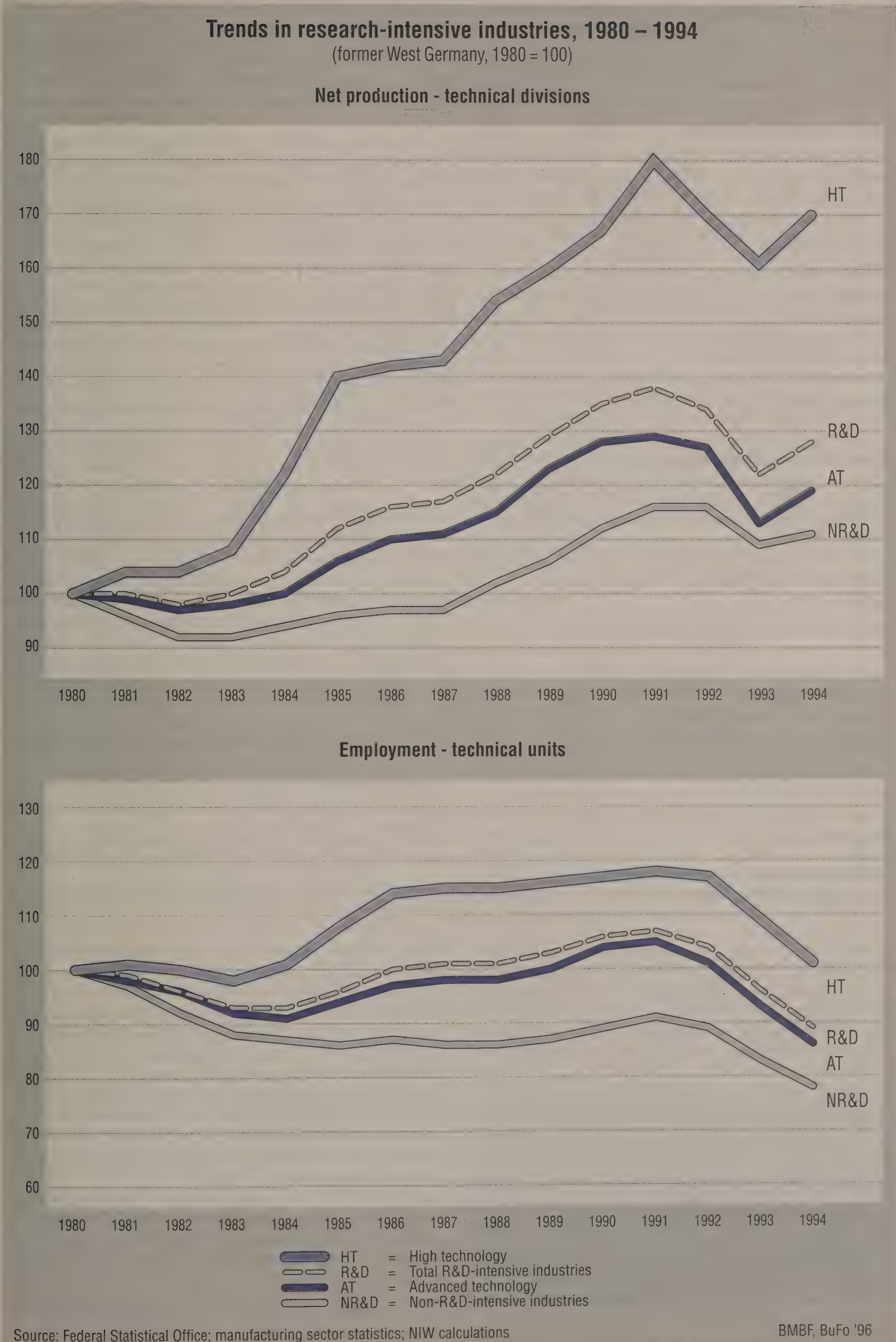

Trends in research-intensive industries, 1980 – 1994
(former West Germany, 1980 = 100)
Net production - technical divisions
180
170
160
150
140
130
120
110
100
90
HT
R&D
AT
NR&D
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
Employment - technical units
130
120
110
100
90
80
70
60
HT
R&D
AT
NR&D
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
HT = High technology
R&D = Total R&D-intensive industries
AT = Advanced technology
NR&D = Non-R&D-intensive industries
Source: Federal Statistical Office; manufacturing sector statistics; NIW calculations
BMBF, BuFo '96

Table II/24

Contributions by industries of the manufacturing sector to GDP in major OECD countries, 1970 to 1992 (%), hourly productivity 1992

Industry	West Germany	USA	Japan	France[1])	Italy[1])	UK
R&D-intensive industries						
1970 to 1972	15.1	10.1	13.0	10.9	8.9	10.4
1980 to 1982	14.7	9.4	12.9	9.1	8.2	8.6
1990 to 1992	14.2	8.4	13.7	8.8	7.0	8.1
High technology						
1970 to 1972	4.2	3.3	3.1	2.2	1.8	3.3
1980 to 1982	3.7	4.4	4.3	2.7	2.0	3.2
1990 to 1992	3.7	3.8	4.4	2.6	1.9	3.2
Advanced technology						
1970 to 1972	11.0	6.8	9.9	8.7	7.1	7.1
1980 to 1982	11.0	5.0	8.6	6.4	6.2	5.4
1990 to 1992	10.5	4.6	9.4	6.3	5.1	4.9
Non-R&D-intensive industries						
1970 to 1972	20.9	13.9	21.4	16.8	18.5	17.4
1980 to 1982	16.4	11.0	16.3	13.3	16.7	12.9
1990 to 1992	15.1	9.3	15.0	12.2	14.7	11.7
Manufacturing sector						
1970 to 1972	36.1	24.0	34.4	27.8	27.5	27.8
1980 to 1982	31.1	20.5	29.2	22.3	24.9	21.6
1990 to 1992	29.4	17.7	28.7	21.0	21.7	19.8
Hourly productivity ($ purchasing power parity)						
R&D-intensive industries	27	33	24	28	(27)	17
High technology	33	41	25	31	(36)	24
Advanced technology	26	27	24	27	(25)	14
Non-R&D-intensive industries	25	25	19	28	(23)	19
Manufacturing sector	26	28	21	29	(24)	18

[1]) 1990 to 1991, hourly productivity 1991.
Source: OECD, STAN Database, Industrial Structure Statistics, National Accounts; DIW calculations and estimates

in Germany has dropped faster than the world average, even if according to the latest statistics the decline is no longer as dramatic as it used to be in the early years of this decade. Germany's patent activities in most of the technology areas are currently changing more slowly than the world average.

> The structures of technological performance can be measured in terms of specialisation. Specialisation in foreign trade means that the ratio of exports to imports is higher than the industry average. A high level of patent specialisation shows that the share of patents relevant to the world market which a country holds in a particular technology area is higher than the average share held of all patents with global market relevance.

There is a close link between the aggregate national expenditure on research and development and the level of specialisation or of technological niche strategies of national economies. Large national economies can offer the most complete range of technologies. Internationally, Germany specialises primarily in R&D-intensive commodities. However, Germany's specialisation trend over the last few years has suggested an increasing concentration on fewer and fewer areas of R&D-intensive technologies. The degree of concentration is also increasing in the USA, albeit slowly. Nevertheless the USA is still the national economy with the highest level of technological diversification. Japan, on the other hand, is gradually redressing the balance, thus trying to create a broader basis for patent activities in more technological areas.

Both the positive and the negative aspects of the German portfolio reflect a balance of patent specialisation and foreign trade specialisation (cf. Figure II/13). Home electronics, communications, EDP instruments and high technology, in other words, the entire range of microelectronics and its applications have traditionally been technological weaknesses of the German economy. Neither the trend of patent applications nor the changes in R&D expenditure are at present giving rise to hopes for a turnaround regarding product groups based on microelectronics. To what extent German companies manage to take advantage of the dynamic development of communications technology remains to be seen. It is remarkable, though, that there is a general decline in patent applications in the areas of pharmaceuticals as well as power plant and turbine technologies. However, in these areas decreasing patent activities compare with a relatively strong and robust position in world trade which so far has been hardly affected by declining patent activities. But patent activity as an early indicator could already point to forthcoming weaknesses in these areas as well. In the other areas of the mechanical engineering and chemical industries, however, Germany has clear relative advantages in terms of both technology and foreign trade specialisation.

What is striking is the almost complementary structure of the German and Japanese specialisation patterns. Japan is strong in those technological areas where Germany has weaknesses and vice versa. The technological strengths of the USA include aerospace technology, many aspects of the chemical industry as well as modern microelectronics and its most important applications with the exception of consumer electronics.

Foreign trade in research-intensive commodities

The research-intensive part of the business enterprise sector is greatly involved in international competition. Over the last 25 years the share of high-tech goods in global trade with manufactured goods has grown considerably. As a rule, the ratio of total trade turnover to national income in research-intensive sectors is higher than average. In 1993 and the year before the share of R&D-intensive goods in total global exports amounted to 45 %. By world trade standards Japan has been the greatest exporter of R&D-intensive commodities since 1991. In 1993 alone Japan accounted for roughly 21 % of the total exports of all Western industrialised countries. The USA ranked second with just under 19 %, followed by Germany with a good 16 %. In 1994 R&D-intensive goods, totalling DM 320 billion, accounted for about 49 % of German manufactured exports; the share of imported R&D-intensive goods in total manufactured imports was 38 % (DM 200 billion).

Foreign trade with research-intensive goods is not a one-way business. There are close relations between technology provider and technology recipient. Especially those countries which themselves hold a strong position in producing new technologies are demanders for such technologies in international markets. Imports push national economies into a deficit; on the other hand, they provide access to foreign know-how, thus contributing to productivity gains. In Germany and the USA there is a particular demand for high technology in the home markets (4 % of domestic demand). In the field of advanced technologies Germany and Japan are the leaders (9 % of domestic demand).

In Germany different levels of specialisation in the area of advanced technologies are absolutely exceptional. Almost all advanced technologies produce higher export surpluses than other goods. The range of products with typically high export surpluses includes almost all chemicals (ranging from research-intensive basic substances to products for private consumption, care products and therapeutic agents), mechanical engineering products (special industry machinery, metal working machines and other special machinery), road and rail vehicles, medical instruments, meters, power generators as well as high-performance ceramics. This goes to show that there is a wide and comprehensive range of products, a fact which is very positive for international trade. It also implies that the risks of sector trends are relatively low in spite of the dominant position of capital goods. Given the large number of strong points of German providers of advanced technologies there obviously have to be some weaknesses as well. These are areas related to microelectronics such as office machines and communications technology, power distribution facilities as well as parts of the photo and optical industries.

The other side of Germany's specialisation in advanced technologies is relatively weaker export-import ratios for high technologies. Only 15 % of manufactured exports are produced by these industries (USA 30 %, Japan 19 %). Some high-tech product groups, however, have very strong competitive positions. These include areas of the chemical industry (pharmaceuticals and active substances, new plastics, crop protection agents) and some parts of electrical engineering (especially medical diagnostic equipment) as well as of metrology, test engineering and control technology. On the other hand, the export-import ratio is particularly low in the case of aircraft and spacecraft and radioactive substances (whose market performance is less market-driven), EDP, telecommunications and semiconductor components.

The USA for its part is highly specialised in high technologies. This stable position of the USA in the field of high technologies is attributable, among other things, to its great R&D commitment in the military area which incidentally also applies to France and the UK. Japan has extraordinary advantages in the areas of both advanced technologies and high technologies. But the share of imported research-intensive commodities in the Japanese home market is much lower than in countries of comparable size.

Germany is the leading technology provider in the European region and over the years has constantly improved this position. A good 40 % of all research-intensive goods exported in recent years from the EU to third countries was of German origin. But compared with the USA and Japan Germany suffers specialisation disadvantages with regard to R&D-inten-

Figure II/13

Specialisation technology (patents) and product groups (world trade)

RPA (relative patent activity); calculated for 1990 to 1993; *positive* – relative specialisation advantage – the share of patents in this field is larger than for total patents; *negative* – relative specialisation disadvantage.

RWS (relative world trade share); calculated for 1993; *positive* – relative specialisation advantage – the product group's share of exports is larger than total manufactured goods; *negative* – relative specialisation disadvantage.

Source: EPTA Database of the EPO; ISI calculations

BMBF, BuFo '96

sive goods exclusively based on high technology. In the case of advanced technologies Germany has the advantage over the other two countries even though this does not in every case need to go hand in hand with high export volumes.

Whereas during the last few years the expansion of world trade in R&D-intensive commodities has only brought minor advantages for highly industrialised economies, newly industrialised countries in Asia in particular and also developing countries catching up benefited from this development. Their share in world trade with manufactured goods has grown continuously and in 1993 reached almost 23 %. This trend is reflected in steadily increasing market shares for R&D-intensive goods. In 1993 a total of about 16 % of R&D-intensive imports came from non-OECD countries, and 60 % of this volume originated in newly industrialised Asian countries. The trend continues to grow strongly.

With regard to some product groups the non-OECD countries are today even among the large-scale exporters (office machines and accessories 25 %; radios 65 %). They have developed into competitors which the industrialised countries need to take seriously. Especially information technology products from non-OECD countries are today playing an important role. In all associated product groups their shares are clearly above the average of R&D-intensive goods as a whole. Japan is likely to come under particular pressure since the supplies from newly industrialised Asian countries are very similar to the range offered by Japan. Germany's technology goods are not that strongly exposed to competition from low-wage countries. The R&D-intensive product groups that are relevant for Germany, i.e. mechanical engineering, automotive products as well as most chemicals, have so far encountered only few competitive suppliers from non-OECD countries in the world market. But this situation could change once the countries of the former Eastern bloc some of which are traditional capital goods producers have completed their economic restructuring process and further efforts by Japan to diversify its industrial and export structures have been successful.

Macroeconomic importance of research-intensive sectors in international comparison

To assess the macroeconomic importance of research-intensive industries it is necessary to look at their contribution to overall production as well as to employment and income. In West Germany, the USA and Japan half of industrial value added in 1992 was accounted for by research-intensive industries. The contribution of R&D-intensive sectors to total GDP is much higher in Germany and Japan, with 13.5 %, than in the USA (8.5 %), France, Italy and the UK (cf. Table II/24).

Also in terms of production structure Germany comes top of the list in the field of advanced technologies. With 3.5 % even high technology in the narrower sense contributes almost as much to overall value added in Germany as it does in the USA and Japan. Despite disadvantages of specialisation of the West German business enterprise sector in high-tech areas its importance in terms of value added by industry as a whole is only slightly less than that of Japan and the USA and considerably higher than that of other European countries. The reason is the great contribution of the business enterprise sector to Germany's total economic performance.

Since the late 1970s the R&D-intensive sector has increased its contribution to industrial production in West Germany from about 42 % to 45.5 %. Three quarters are accounted for by advanced technologies. This also applies to employment where the share rose from 40 % to a good 43 %. The development of production and employment highlights the function of R&D-intensive industries as a driving force of the economy as a whole. Major pillars of the above-average development of R&D-intensive industries were high-tech areas which invariably made outstanding contributions to industrial growth.

10. International comparison of resources for research and development

The description of a national research and technology system by means of statistics and indicators would be incomplete without an international comparison. Such a comparison, however, needs to be based on *consistent* data relating to research and development in the countries of interest, i.e. in the following the G7 states. The OECD and EU make such data available on a regular basis; the data are determined according to a widely homogeneous methodology. EU surveys are primarily related to budget appropriations for R&D, i.e. budget data applying exclusively to the public sector. The OECD complements these data by determining the corresponding budget data for all non-EU OECD countries. An important issue covered by the extensive OECD work in the field of R&D – and also by the following presentation – is actual *gross domestic expenditure on R&D (GERD)* as well as the indicators derived from this indicator. GERD comprises all funds spent in a country to perform R&D, irrespective of their source of finance. It also includes all funds from abroad and from international organisations earmarked for R&D in the respective country, but does not cover the payments made by that country to other states or to international organisations for performing R&D activities there.

In 1993, the last year for which data for all G7 states are available, gross domestic expenditure on R&D by all G7 countries totalled $ 347 billion; this is 4.2 % up on 1991 ($ 333 billion). This clearly shows that the trend towards declining growth rates for R&D funds which was already observed in the second half of the 1980s in the countries under consideration has picked up: At the time R&D expenditure rose by an annualised 7 % compared with 11 % between 1981 and 1985. The rates of change of the individual G7 countries which form a mean of 4.2 % vary considerably. In the period from 1991 to 1993 the UK, with a growth of 10.8 %, could boast the highest rate of increase. Thus the phase of sub-average increases characteristic of previous years had come to an end in that country. In

addition to the UK, also Canada (7.2 %) and France (5.9 %) experienced a growth that was considerably higher than the average. The other G7 states have only sub-average increase rates: Japan 3.9 %, USA 3.5 %, Germany 3.0 % and Italy 2.7 %.

These differences in growth rates, however, were not enough to change the ranking of G7 states of previous years which had been derived from absolute R&D expenditure levels.

Also in 1993 the USA had the highest gross domestic expenditure on R&D in nominal terms, amounting to $ 166 billion. It thus accounted for slightly less than half of the total R&D funds spent by the G7 states. Japan and Germany follow in second and third place, with Japanese R&D expenditure (1993: $ 74 billion) being about half of that of the USA and twice as high as that of Germany.

Germany's lead ($ 37 billion) over France which held fourth place is much less commanding. With $ 26 billion France spent about 30 % less than Germany on R&D in 1993. R&D expenditure by the UK (fifth rank) amounted to slightly less than $ 22 billion in 1993, followed by Italy with $ 13 billion and Canada with a good $ 8 billion (cf. Table II/25).

The absolute levels of gross domestic expenditure on R&D and their changes, however, do not provide an adequate basis for a comparison of the research efforts undertaken by the various countries. First, the absolute figures (also) reflect considerable differences in size between the national economies under consideration and second, the rates of change are the result of different price developments.

These two qualifications do not apply if instead of absolute levels the shares of GDP devoted to R&D in the various countries are considered. Today this is the most common indicator for measuring and comparing national research performances.

As the decline in growth which had accelerated since the beginning of this decade usually affected R&D expenditure more than GDP, the period of continuously growing shares of GDP devoted to R&D in the countries under consideration came to an end in the early 1990s. For all countries concerned, except for the UK, this indicator was lower in 1993 than in 1991. In Germany this downward trend started slightly earlier than in the other G7 states which was, among other things, attributable to particularly high increases in GDP associated with unification. In 1989 the share of GDP devoted to R&D was still 2.87 %, by 1991 it had dropped to 2.61 % and in 1994 it was an estimated 2.33 %. A similar relative decrease was only observed in the USA where in 1991 2.84 % of GDP was spent on R&D, while in 1994 it was only 2.54 %.

Table II/25

Gross domestic expenditure on R&D (GERD) in selected countries

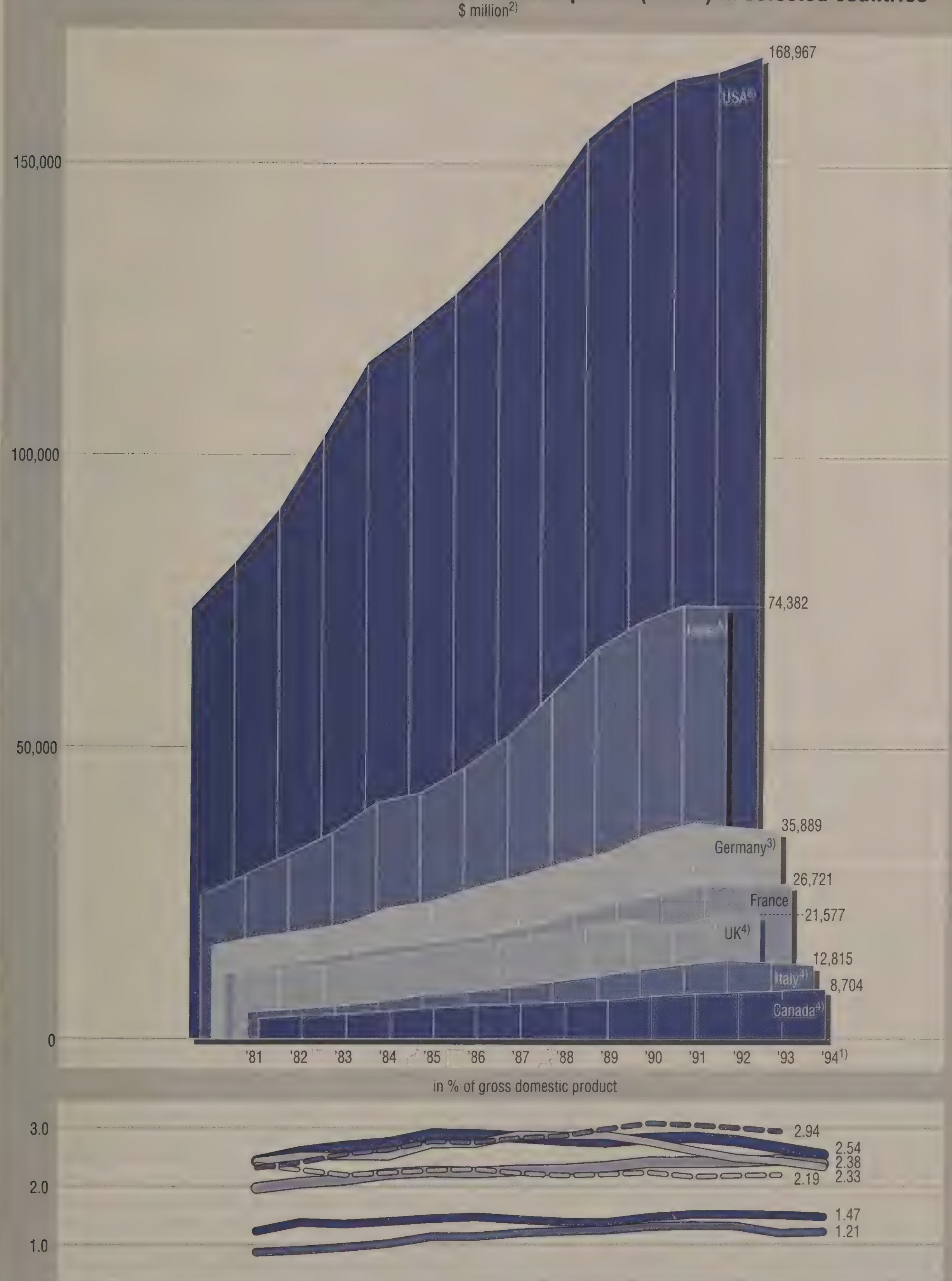
Country	1981	1989	1991	1992	1993	1994[1])
	– $ million[2]) –					
Germany[3])	15,985	30,293	35,470	37,246	36,534	35,889
France	11,114	21,500	24,962	26,659	26,431	26,721
UK	11,613	19,142	19,467	21,294	21,577	.
Italy[4])	4,604	10,761	12,862	13,615	13,214	12,815
Japan[5])	24,652	59,363	71,585	74,621	74,382	.
USA[6])	73,693	143,821	160,750	164,919	166,299	168,967
Canada[4])	3,456	6,707	7,812	8,106	8,376	8,704
	– % of GDP[7]) –					
Germany[3])	*2.43*	*2.87*	*2.61*	*2.48*	*2.43*	*2.33*
France	*1.97*	*2.33*	*2.41*	*2.42*	*2.45*	*2.38*
UK	*2.37*	*2.20*	*2.16*	*2.18*	*2.19*	.
Italy[4])	*0.87*	*1.24*	*1.32*	*1.31*	*1.31*	*1.21*
Japan[5])	*2.32*	*2.98*	*3.05*	*3.00*	*2.94*	.
USA[6])	*2.43*	*2.76*	*2.84*	*2.78*	*2.66*	*2.54*
Canada[4])	*1.23*	*1.37*	*1.51*	*1.51*	*1.50*	*1.47*

[1]) Provisional OECD data, based partly on national estimates, partly on OECD estimates.
[2]) Nominal expenditure, in US $ purchasing power parities.
[3]) 1989, 1991 and 1992 break in series; 1992 to 1994 revised estimates; up to and including 1989 former West Germany, from 1991 onwards Germany as a whole.
[4]) 1993 provisional.
[5]) R&D expenditure overestimated or based on overestimated data.
[6]) Excludes most or all capital expenditure; 1991 break in series.
[7]) GDP: gross domestic product.

Source: OECD (1995/2) and BMBF calculations — Rounding error

Figure II/14

Gross domestic expenditure on research and development (GERD) in selected countries



1) Provisional.
2) Nominal expenditure in US $ purchasing power parities.
3) Estimates for even years; 1991 and 1992 break in series; 1993 revised estimate, up to 1990 former West Germany, from 1991 onwards Germany as a whole.
4) 1993 provisional.
5) R&D expenditure overestimated or based on overestimated data.
6) Excludes most or all capital expenditure.

Source: OECD (1995/2) and BMBF calculations

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Table II/26

Gross domestic expenditure on R&D (GERD) per capita population in selected countries

– $ –[1])

Country	1981	1989	1991	1992	1993
Germany[2])	259	488	444	462	450
France	205	381	438	465	458
UK	206	334	337	367	371
Italy[3])	81	187	227	239	235
Japan[4])	210	482	578	600	597
USA[5])	320	578	638	647	645
Canada[3])	142	255	289	285	291

[1]) Nominal expenditure, converted into US $ purchasing power parities.
[2]) 1989, 1991 and 1992 break in series; 1992 and 1993 revised estimates; up to and including 1989 former West Germany, from 1991 onwards Germany as a whole.
[3]) 1993 provisional.
[4]) R&D expenditure overestimated or based on overestimated data.
[5]) Excludes most or all capital expenditure; 1991 break in series.
Source: OECD (1995/2) and BMBF calculations — Rounding error

Japan was the only G7 state which in 1991 managed to pass the 3 % mark. But by 1993 this figure had dropped again to 2.94 %.

The increase in R&D expenditure in France which was higher than in Germany while at the same time GDP growth was lower resulted in a reversal of the positions of these two countries: Since 1993 France, with shares of 2.45 % in 1993 and 2.38 % in 1994, has had higher levels than Germany (1993: 2.43 %; 1994: 2.33 %) and now takes Germany's former third place behind Japan and the USA (cf. Table II/25)[16]).

Another statistical indicator used to compare national research efforts is the per capita gross domestic expenditure on R&D in the various countries. With $ 645 the USA still had the highest per capita expenditure on R&D in 1993. Like the trend identified for absolute levels this indicator also shows that the lead over the country coming second – since 1990 Japan and no longer Germany – has shrunk compared with the 1980s. In 1981 the per capita expenditure on R&D by the runner-up (Germany) which amounted to $ 259 was still 20 % below that of the USA; in 1993 the lead over Japan ($ 597) had shrunk to only 8 %. In terms of this indicator not only Japan, but also Italy and France caught up considerably in the 1980s: In 1981 French per capita expenditure on R&D was $ 205 making France the number five in the 1980s. In 1993, with $ 458, it came third among the G7 countries, leading just ahead of Germany and trailing clearly behind Japan and the USA[17]). Italy has tripled its per capita expenditure since 1981, thus managing to reduce Canada's lead of almost 50 % in 1981 to 20 %. The time series for Germany was also strongly affected by unification. The rise in population figures did not compare with an equally high growth in total R&D expenditure which resulted in a decline of about 10 % in 1991 ($ 444) compared with 1989 ($ 488). If only the years after 1991 are considered, it is again the UK which with 10 % had the highest per capita growth of R&D expenditure, while France (5 %), Italy (4 %) and Japan (3 %) had minor rates of increase and the USA, Germany and Canada did not undergo any major changes (cf. Table II/26).

One of the most important characteristics of a research system is the financing structure of research expenditure. A comparison of the percentage of the countries' gross domestic expenditure on R&D financed by the business enterprise sector is of major importance in this context. At present, corresponding OECD data for the countries under consideration are available up to and including 1993. Since the early 1980s the business enterprise sectors of Japan and Germany have invariably made the highest contributions. In Germany the trend has been declining since 1989. One of the reasons is that the restructuring process in public R&D institutions and the higher education sector in the wake of unification was implemented faster than in the business enterprise sector, a fact which between 1989 and 1991 brought about a significant change in financing shares in favour of government-financed R&D expenditure. After the contribution of the business enterprise sector in Japan had risen continuously from 62.3 % in 1981 to 72.7 % in 1991 there has since been a (relatively strong) downward trend. In 1993 the Japanese business enterprise sector financed 68.2 % of national R&D expenditure. All other countries under consideration, however, whose figures are traditionally very much lower showed rising contributions. Between 1991 and 1993 France boasted the highest increase. In 1993 the French business enterprise sector's contribution to financing R&D, at 46.2 %, was almost four percentage points higher than in 1991 (42.5 %). Despite this sizeable increase France is the only country

[16]) Outside the G7 group Sweden (1993: 3.26 %) and Switzerland (1992: 2.68 %) are among the frontrunners concerning this indicator.

[17]) Again Sweden and Switzerland with $ 549 and $ 618, respectively, are among the top group of the OECD countries.

Table II/27

Financing of gross domestic expenditure on R&D (GERD)

– in % –

Country	financed											
	by business enterprise sector				by government				by others			
	1981	1989	1991	1993	1981	1989	1991	1993	1981	1989	1991	1993
Germany[1])	57.9	63.3	61.7	61.4	40.7	34.1	35.8	36.7	1.4	2.6	2.4	2.0
France[2])	40.9	43.9	42.5	46.2	53.4	48.1	48.8	44.3	5.6	8.0	8.7	9.4
UK[3])	42.0	51.3	50.4	52.1	48.1	35.7	34.2	32.3	9.9	13.0	15.4	15.6
Italy[4])	50.1	46.4	47.8	49.9	47.2	49.5	46.6	45.9	2.7	4.1	5.7	4.2
Japan[5])	62.3	72.3	72.7	68.2	26.9	18.6	18.2	21.6	10.8	9.1	9.2	10.2
USA[6])	48.8	52.2	57.5	58.7	49.3	45.6	40.5	39.2	1.9	2.2	2.0	2.1
Canada[7])	41.3	42.0	41.8	42.3	50.0	44.1	43.4	42.4	8.8	14.0	14.8	14.5

[1]) 1989, 1991 and 1992 break in series; up to and including 1989 former West Germany, from 1991 onwards Germany as a whole; 1993 revised estimate.
[2]) 1993 break in series for contribution by BE sector.
[3]) 1989 break in series.
[4]) 1993 provisional.
[5]) Contribution by business enterprise sector underestimated or based on underestimated data.
[6]) Excludes most or all capital expenditure; 1991 break in series.
[7]) 1993 contribution by business enterprise sector based on non-revised data, hence deviation from revised total; 1993 provisional.

Source: OECD (1995/2) and BMBF calculations — Rounding error

in the G7 group, apart from Canada, where clearly less than half of total R&D performed is financed by the business enterprise sector. Accordingly, the trend for public R&D funds is converse (cf. figure II/15).

In the USA and Germany "Others" – this term covers the private non-profit sector and the sector „abroad" – have for many years made consistent contributions of about 2 %. In all other G7 states, except for Canada, this financing source shows an upward trend. The UK, Japan and Canada have by now reached double-digit figures. In all cases – with the exception of Japan – the relatively high current levels and rates of increase are mainly attributable to foreign contributions. In the UK which with 15.6 % % in 1993 had the highest contribution by "Others" in the G7 group the share of "abroad" that was contained in this percentage was nearly 12 %. The increase by 2.6 % in that country since 1989 is mostly the result of an increase in the share financed by foreign countries. The same is true for Canada where "Others" with 14.5 % in 1993 included a contribution of 10 % from abroad (cf. Table II/27).

Information on financial R&D resources of a country is supplemented by data on personnel working in research and development. One of the most common ratios used in international comparisons is that of research personnel to total labour force (cf. Table II/28). For the USA, however, such data are not available. All through the 1980s Germany came first in the G7 league in terms of this indicator. Since it had suffered a decline since 1990 while Japan had enjoyed continuous increases, there was a change at the top in 1991; since then Japan has had the highest ratio (14.3 R&D personnel per 1,000 labour force in 1993). France and Germany with 12.5 and 12.3 R&D personnel per 1,000 labour force rank second and third, respectively, with France being the only country apart from Japan which could increase this ratio in recent years. The figures for the UK, Italy and Canada have remained constant. There are differences between the G7 countries in terms of the proportion of researchers in total R&D personnel which was also determined. Traditionally it has been Japan which has had the highest figures by far (9.7 R&D staff per 1,000 labour force in 1993), which had even risen by almost 10 % since 1989. However, a methodological qualification needs to be made with regard to Japanese personnel data: Unlike the other countries Japan does not calculate the figures on a full-time equivalent basis, but specifies the number of persons (headcount) so that Japanese figures are likely to be too high compared with those of the other countries.

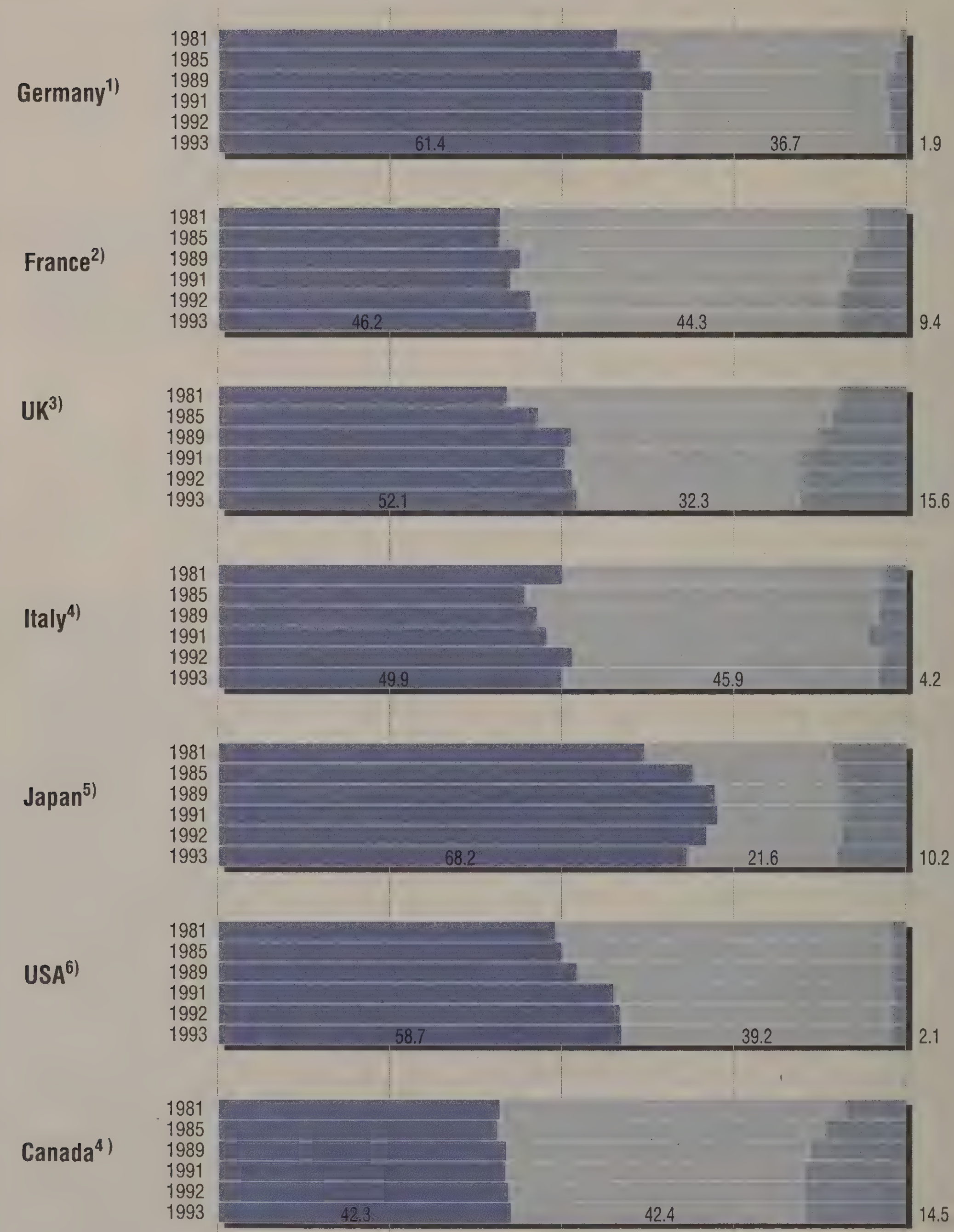
While all indicators reviewed so far were related to gross domestic expenditure on R&D, Table II/29 shows total government R&D expenditure, including funds spent on R&D abroad, as a percentage of GDP. Since the late 1980s France had invariably topped the list (1.27 % in 1993). With 1.12 % the USA ranked second ahead of Germany (0.99 %), while Japan was trailing far behind (0.49 %).

The trend of these shares since 1991 has been inhomogeneous: In Germany the percentage dropped continuously (1.03 % in 1991; 0.96 % in 1994). France, the UK and the USA also had declining trends. The situation was different for Italy and Japan as they had increased their respective shares considerably since 1991 (cf. figure II/16).

Figure II/15

Financing of gross domestic expenditure on research and development (GERD) in selected countries

in %



financed by **BE sector** | financed by **Government** | financed by **others**

1) 1991 and 1992 break in series. 1993 revised estimate.
2) 1992 break in series.
3) 1989 break in series.
4) 1993 provisional.
5) Contribution by BE sector underestimated or based on underestimated data.
6) Excludes most or all capital expenditure.

Source: OECD and BMBF calculations

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Table II/28

R&D personnel per 1,000 labour force in selected countries

– full-time equivalent –

Country	1981		1989		1991		1993	
	total	research-ers	total	research-ers	total	research-ers	total	research-ers
Germany[1])	12.7	4.4	14.3	5.9	13.2	6.1	12.3	5.9
France	10.6	3.6	11.9	5.0	12.0	5.2	12.5	.
UK[2])	11.7	4.7	9.9	4.7	9.4	4.6	9.9	5.0
Italy	4.5	2.3	5.8	3.1	5.8	3.1	.	.
Japan[3])	11.4	6.9	13.8	8.9	14.0	9.2	14.3	9.7
USA	.	6.2	.	7.4	.	7.6	.	7.4
Canada	6.9	3.4	8.2	4.6	8.3	4.7	.	.

[1]) 1989 and 1991 break in series; up to and including 1989 former West Germany, from 1991 onwards Germany as a whole; 1993 revised estimate.
[2]) 1991 break in series.
[3]) Overestimated or based on overestimated data.
Source: OECD (1995/2) and BMBF calculations — Rounding error

Table II/29

Total government R&D expenditure in % of gross domestic product *)

Country	Total %					% of civil R&D expenditure				
	1981	1989	1991	1993	1994[1])	1981	1989	1991	1993	1994[1])
Germany[2])	1.16	1.06	1.03	0.99	0.96	1.05	0.93	0.92	0.91	0.88
France[3])	1.29	1.36	1.38	1.27	.	0.79	0.86	0.88	0.84	.
UK	1.34	0.90	0.87	0.86	0.83	0.72	0.51	0.49	0.49	0.46
Italy[4])	0.56	0.73	0.75	0.80	.	0.52	0.66	0.69	0.74	.
Japan[5])	.	0.46	0.45	0.49	0.50	.	0.43	0.42	0.46	0.47
USA[6])[7])	1.11	1.19	1.16	1.12	1.03	0.50	0.41	0.47	0.46	0.46
Canada[6])	0.60	0.57	0.61	.	.	0.56	0.52	0.58	.	.

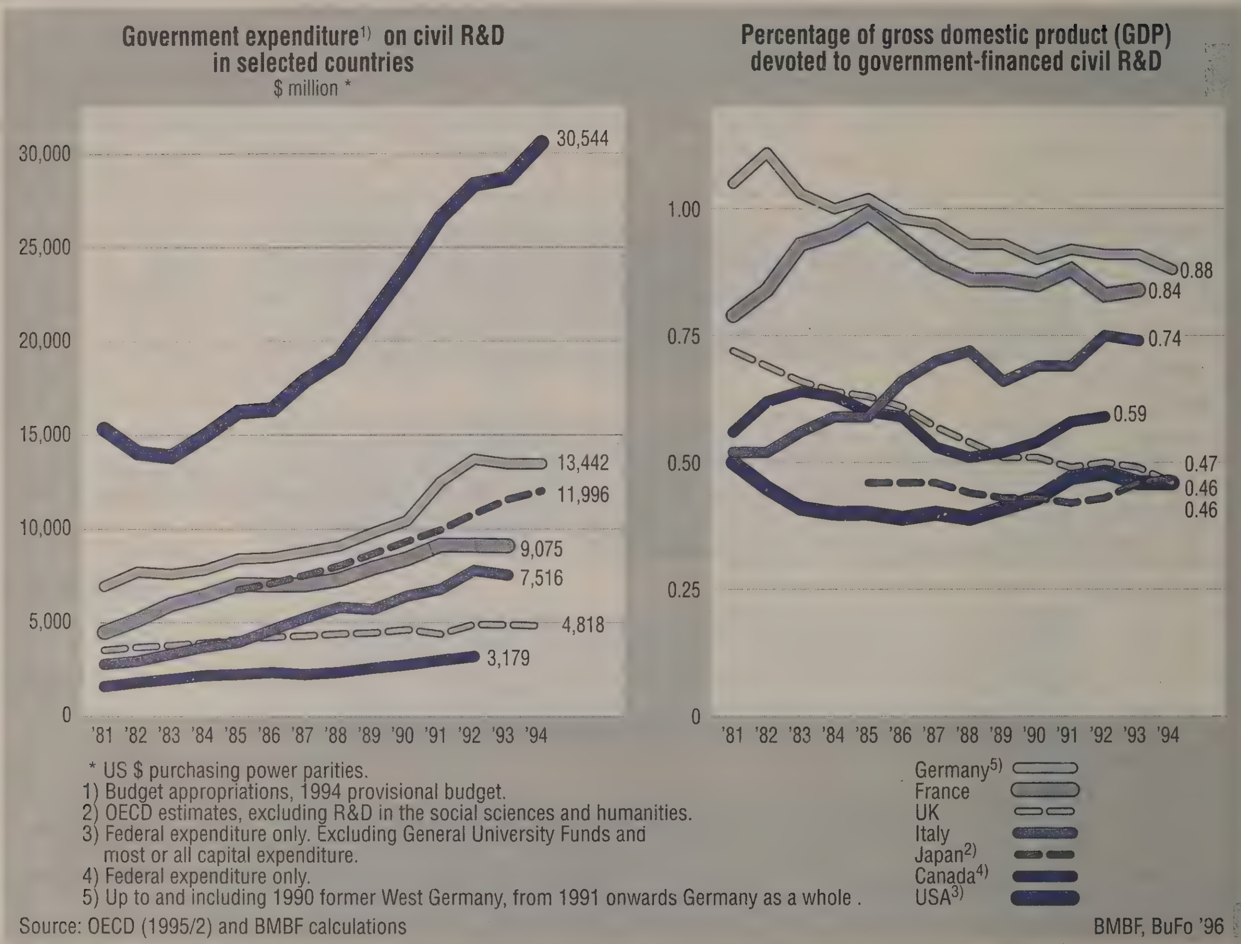
*) Budget appropriations.
[1]) Provisional in some cases.
[2]) 1989 and 1991 break in series; up to and including 1989 former West Germany, from 1991 onwards Germany as a whole; 1993 provisional.
[3]) 1993 break in series.
[4]) 1993 provisional.
[5]) Excluding funds for humanities and social sciences.
[6]) Federal expenditure only.
[7]) Excluding General University Funds and most or all capital expenditure.
Source: OECD (1995/2) and BMBF calculations — Rounding error

As far as the share of GDP devoted to civil R&D is concerned Germany came first also in 1993 with 0.91 %. As in previous years it is followed by France (0.84 %) and Italy (0.74 %). There are major differences between the countries in the shares of civil research in total government R&D expenditure: While in Germany, Japan, Italy and Canada civil research accounts for more than 90 % of total expenditure, it is roughly 66 % in France, about 57 % in the UK and only little more than 40 % in the USA.

As mentioned earlier, publicly financed R&D expenditure (budget appropriations) broken down by research objective is determined on the basis of surveys conducted regularly by the European Union; at present data are available which relate to final budget appropriations for 1993 and to provisional budget appropriations for 1994.

In 1993 the EU member states appropriated a total of 53.2 billion ecus for R&D (1993: 1 ecu = DM 1.94); this is 1.6 % down on 1992 (54.1 billion ecus). While during the 1980s France invariably used to have the highest government R&D expenditure within the EU, Germany's expenditure – measured in respective prices – has been higher since 1991. In 1992 the funds appropriated by the Federal and Länder governments amounted to 15.4 billion ecus, in 1993 to 16.1

Figure II/16



billion ecus; this is an increase by a little less than 5 %. The corresponding budget appropriations in France amounted to 13.2 billion ecus in 1992 and rose by almost 3 % to 13.6 billion ecus. The UK came third with 6.8 billion ecus in 1992 and 6.9 billion ecus in 1993. In 1994 these three countries together accounted for nearly 70 % of the funds appropriated by all EU member states for R&D. The slight aggregate decline in budget funds appropriated to R&D results from a plunge in Italy by 23 %, drops of some 17 % and 16 % in Finland and Sweden, respectively, and a 12 % fall in Spain.

In 1993 the highest R&D expenditure per capita was registered in France (237 ecus) and Sweden (236 ecus). Germany (199 ecus), Finland (155 ecus) and the Netherlands (144 ecus) follow far behind, with the funds appropriated for R&D in per-head terms by the Netherlands equal the average of all EU members.

In the period from 1985 to 1993 the annual rate of increase of government R&D expenditure averaged over all EU member states was 4.8 %. With 6.9 % Germany had a higher rate, while France, with 4.0 %, was slightly below average. As the only country among the 15 member states considered here the UK had a lower amount in money terms in 1993 than in 1985. As demonstrated in a comparison with the 1.3 % rate of change for civil R&D, this mainly results from the fact that fewer funds were allocated to military research. The South European countries Portugal and Spain had particularly high growth rates for total R&D expenditure with 22.8 % and 12.3 %, respectively.

In this context a comparison with annual GDP growth is quite informative. From 1985 to 1993 the rate of increase averaged over all 15 EU member countries was 6.3 %. This implies that publicly financed R&D expenditure has grown less than GDP. In other words, "R&D intensity" has slackened. Departing from this pattern, growth of Austria's expenditure on R&D was almost double that of its GDP. Particularly high negative deviations were identified in Sweden, the UK and especially Greece. In Germany growth rates of GDP and R&D expenditure tally at almost 7 % each.

Table II/31 gives an overview of total government R&D expenditure by EU member states and the EU as a whole broken down by socio-economic research objective as well as of any changes over the period from 1985 to 1994. Traditionally, the focus is on the percentage of non-civil research. Averaged over all EU member states, it was some 20 % in 1994. In 1985 it was still nearly 26 %. It was the high level of funds appropriated for defence research in France and especially the UK, accounting for 32.4 % and 44.5 %, respectively, of total national R&D expenditure, that

Table II/30

Total government R&D expenditure of the countries of the European Union[1]) by individual member states

– in % –

Country	1985	1991	1994
Germany	25.0	25.8	25.3
France	26.7	25.9	25.4
UK	19.5	14.6	15.9
Total	**71.2**	**66.3**	**66.7**
Belgium	1.9	1.9	2.2
Denmark	1.0	1.2	1.2
Greece	0.4	0.4	0.4
Spain	3.0	4.8	4.2
Irland	0.3	0.2	0.3
Italy	11.4	13.4	12.2
Netherlands	4.2	4.0	4.1
Austria	1.5	1.7	2.2
Portugal	0.4	0.8	1.0
Finland	1.1	1.6	1.6
Sweden	3.7	3.6	3.9
Total	**100.0**	**100.0**	**100.0**

[1]) At 1985 purchasing power parities and prices.
Source: Eurostat (1994 provisional appropriations)
Rounding error

contributed to the relatively high mean value. In Sweden about 20 % of government R&D expenditure goes into defence research, the percentages in all other countries are far below this level (Spain 11.3 %, Germany 8.4 %, Italy 8.9 %).

Table II/32 provides an overview of government R&D expenditure of EU member states broken down by groups of research objectives. Apart from the declining share of defence which the table also reflects for the Europe of twelve, it highlights the increase in the share of General University Funds from 21.2 % in 1985 to 28.5 % in 1994 as well as the almost completely diametrical trend of "Technological objectives" (28.9 % in 1985; 22.5 % in 1994).

11. Patent and licence transactions with foreign countries

The indicators which describe receipts from and expenditure on patent and licence transactions, research and development contracts and engineering services and are usually referred to as "Technological Balance of Payments" need to be interpreted with special care and expertise.

Table II/32

Government R&D expenditure of EU member states by research objectives

– in % –

Group of research objectives (according to NABS[1])	1985	1991	1994	
	EUR 12			EUR 15[2])
Human and social objectives (NABS chapters 2, 3, 4, 8)	9.5	10.7	10.9	11.1
Technological objectives (NABS chapters 1, 5, 7, 9)	28.9	25.6	22.5	22.0
Agriculture (NABS chapter 6)	2.8	3.8	3.7	3.7
Research financed from Gerneral University Funds (NABS chapter 10)	21.2	23.4	28.5	29.6
Non-oriented research (NABS chapter 11)	10.9	12.4	13.0	13.0
Other civil research (NABS chapter 12)	0.9	1.3	1.4	1.5
Defence (NABS chapter 13)	25.8	22.8	19.8	19.1
Total	**100.0**	**100.0**	**100.0**	**100.0**

[1]) Nomenclature for the analysis and comparison of scientific programmes and budgets (1985 and 1991: NABS 1983; 1994: NABS 1992); cf. Table II/31.
[2]) Including Austria, Finland and Sweden.
Source: Eurostat (1994 provisional budget appropriations)
Rounding error

In view of the growing diversity of ways and means of exchanging technical knowledge these indicators cannot provide a complete picture of international technology transfer nor an adequate basis for assessing the level of technological performance of a particular country.

Factors not covered by the Technological Balance of Payments, although they are of great importance for the transfrontier exchange of technical knowledge, are foreign trade in high-tech manufactured goods, sales of industrial plants and the establishment of production and distribution facilities outside the territory of the country in which a company is based (direct investment).

By buying enterprises working in new technology areas and based in leading research regions companies can acquire new technical know-how[18]).

[18]) Cf. "Germany's Technological Performance", background-material to the report on behalf of the BMBF, study by the German Institute for Economic Research (DIW), Bonn 1996, p. 14.

Table II/31

Government R&D expenditure of EU member states by individual research objectives, 1985 and 1994 (budget appropriations) *)

– in % –

Research objective according to NABS chapters (NABS 1992)[1])	B		DK		D[2])		GR		E		F		IRL	
	1985	1994	1985	1994	1985	1994	1985	1994	1985	1994	1985	1994	1985	1994
1. Exploration and exploitation of the Earth	3.1	1.5	1.3	1.8	2.1	2.6	5.5	3.9	6.7	2.6	1.5	0.8	0.9	0.3
2. Infrastructure and general planning of land use	0.7	0.5	2.4	2.3	1.9	1.5	0.5	1.3	4.3	0.5	3.1	0.6	4.0	4.8
3. Control of environmental pollution	2.5	1.6	1.5	4.1	3.1	4.2	3.4	4.1	0.4	2.4	0.5	1.8	0.8	1.3
4. Protection and improvement of human health	2.7	1.5	3.3	1.6	3.0	3.3	7.6	6.0	2.5	5.6	4.0	4.5	4.3	3.7
5. Production, distribution and rational utilisation of energy	11.5	2.9	6.5	2.2	12.6	3.8	2.6	3.7	7.9	1.7	7.8	3.9	1.3	0.2
6. Agricultural production and technology	7.0	4.1	7.4	6.7	2.0	2.6	27.1	12.6	7.3	4.8	3.5	3.9	28.7	12.9
7. Industrial production and technology	16.4	12.2	21.1	12.9	14.1	12.7	7.7	8.1	18.5	20.1	12.1	6.6	28.9	23.3
8. Social structures and relationships	0.7	2.6	4.2	6.9	2.3	2.4	5.6	3.6	0.8	1.1	2.6	0.7	7.5	10.6
9. Exploration and exploitation of space	6.6	13.2	3.2	3.3	3.9	5.6	0.6	0.3	3.7	8.1	5.6	10.7	1.6	3.9
10. Research financed from General University Funds	22.2	35.2	31.0	35.0	31.4	38.8	28.3	46.1	21.3	32.8	11.9	14.5	19.7	34.6
11. Non-oriented research	22.4	18.6	17.7	22.6	11.4	13.8	6.1	7.1	18.2	7.0	14.4	18.1	2.2	4.3
12. Other civil research	2.7	6.0	–	–	0.1	0.2	2.0	0.5	2.1	1.9	1.7	1.6	–	–
Civil R&D as % of total	**98.5**	**99.8**	**99.5**	**99.5**	**88.1**	**91.6**	**97.1**	**98.3**	**93.7**	**88.7**	**68.7**	**67.6**	**100.0**	**100.0**
13. Defence	1.5	0.2	0.5	0.5	11.9	8.4	2.9	1.7	6.3	11.3	31.3	32.4	–	–
Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

*) 1985 final budget appropriations, 1994 provisional budget appropriations.
[1]) Breakdown according to Nomenclature for the analysis and comparison of scientific programmes and budgets (NABS 1992); 1985 data according to NABS 1983, 1994 data according to NABS 1992.
[2]) For 1994 transfer of R&D expenditure from NABS chapter 1 to NABS chapter 3 in keeping with NABS 1992.
Source: EU

Rounding error

Another method of technology transfer is the exchange of scientific personnel.

Even though these transactions are not the immediate object of the Technological Balance of Payments, they have a certain influence on the level of relevant receipts and expenditure.

At regular intervals, the Deutsche Bundesbank reports on the development of patent and licence transactions between the Federal Republic of Germany and other countries as well as on the exchange of technical know-how through service transactions[19]); the results are based on reports submitted pursuant to the Foreign Trade and Payments Ordinance.

At the international level, data pertaining to these indicators are compiled by the Organisation for Economic Cooperation and Development (OECD).

In view of the varied use made of these data, on the one hand, and the problems involved in their expert interpretation, on the other hand, a manual containing recommended guidelines for the compilation and interpretation of statistics on the Technological Bal-

[19]) Monthly Reports of the Deutsche Bundesbank (last in April 1992), (monthly) statistical supplements to the Monthly Reports as well as special publications (Technologische Dienstleistungen in der Zahlungsbilanzstatistik, May 1994).

I		NL		A		P		FIN		S		UK		EUR 12		EUR 15		EU	
1985	1994	1985	1994	1985	1994	1985	1994	1985	1994	1985	1994	1985	1994	1985	1994	1985	1994	1985	1994
1.3	0.9	0.6	0.4	.	1.8	.	6.8	.	2.1	.	0.4	1.8	1.9	1.7	1.7	.	1.7	1.5	2.1
1.1	0.5	4.1	4.6	.	1.4	.	4.2	.	3.3	.	5.9	1.2	1.8	2.1	1.3	.	1.5	0.6	5.0
1.0	2.4	3.3	5.8	.	2.7	.	1.7	.	2.4	.	3.8	1.1	2.0	1.6	2.9	.	2.9	5.4	7.1
4.6	6.1	2.7	2.7	.	2.1	.	7.9	.	3.1	.	1.0	3.6	7.2	3.6	4.5	.	4.3	4.2	5.0
19.7	3.4	4.6	3.1	.	0.7	.	3.3	.	3.5	.	2.4	4.5	1.1	9.6	3.2	.	3.1	55.8	19.4
3.8	2.4	4.5	4.7	.	3.3	.	11.0	.	7.2	.	1.2	4.6	5.2	3.7	3.7	.	3.7	2.8	5.8
20.6	10.3	15.5	14.8	.	6.8	.	14.5	.	32.9	.	5.1	6.7	8.0	12.8	10.4	.	10.5	26.7	39.7
1.1	3.6	2.6	2.3	.	1.7	.	3.0	.	6.6	.	8.0	1.2	2.7	2.0	2.2	.	2.4	0.5	1.5
7.1	9.1	0.9	4.5	.	0.0	.	0.4	.	1.9	.	1.6	1.8	3.1	4.2	7.2	.	6.7	1.0	0.4
21.7	40.5	43.4	35.5	.	64.8	.	34.3	.	24.2	.	39.1	14.6	17.0	21.0	28.5	.	29.6	–	–
7.5	8.4	10.2	13.1	.	14.5	.	8.7	.	10.8	.	12.7	6.5	4.9	10.9	13.0	.	13.0	1.3	1.0
0.6	3.5	4.5	4.9	.	0.1	.	2.5	.	–	.	–	0.3	0.5	0.9	1.4	.	1.5	–	13.0
90.1	**91.1**	**96.9**	**96.6**	**.**	**100.0**	**.**	**98.3**	**.**	**97.9**	**.**	**81.1**	**48.1**	**55.5**	**74.2**	**81.2**	**.**	**80.9**	**100.0**	**100.0**
9.9	8.9	3.1	3.4	.	0.0	.	1.7	.	2.1	.	18.9	51.9	44.5	25.8	19.8	.	19.1	–	–
100.0	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

ance of Payments was prepared and published a few years ago. It leans heavily on the Frascati Manual which provides a proposed standard practice for surveys of research and experimental development.

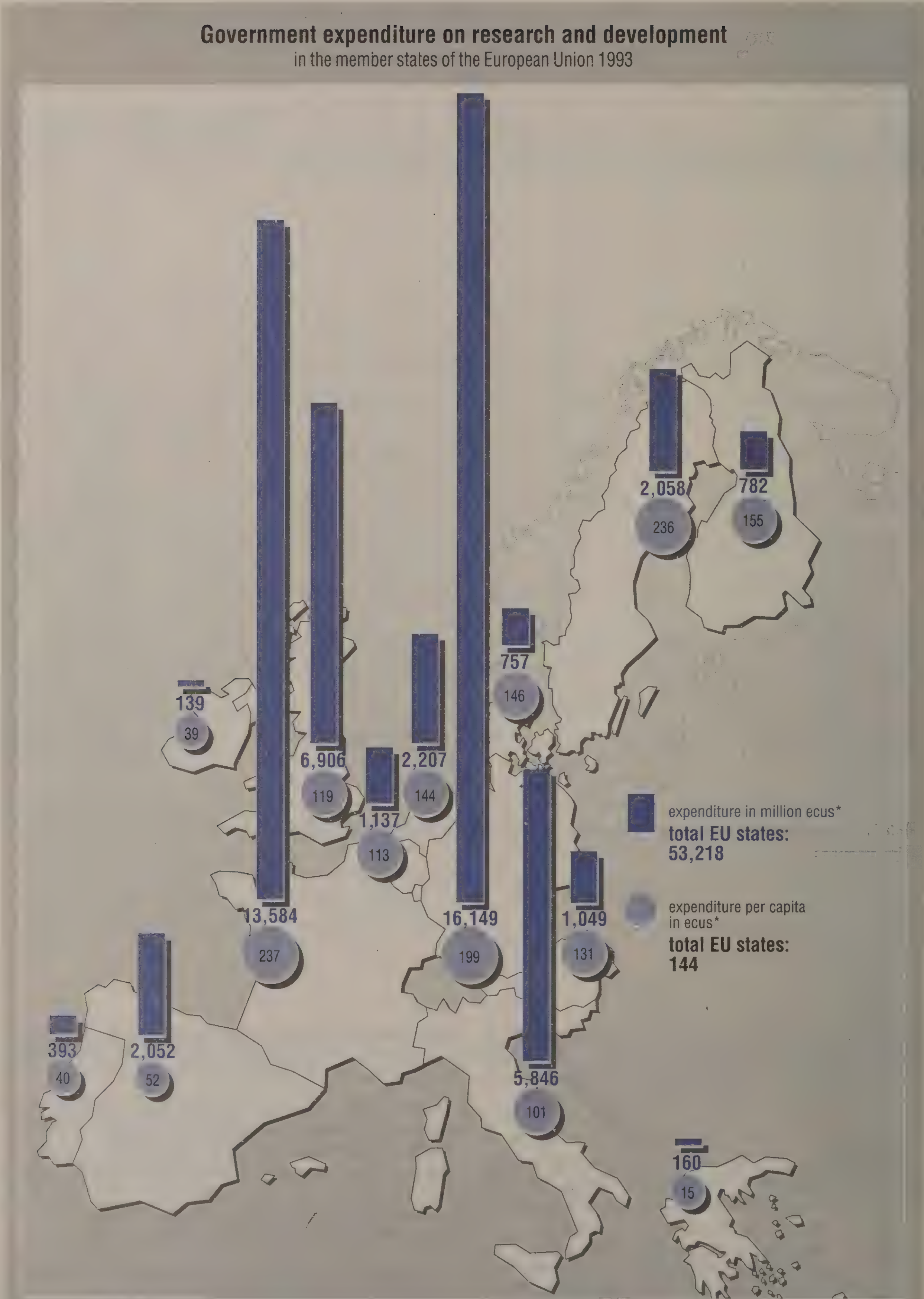
Since the early 1970s the long-term trend of receipts from and expenditure on patents, inventions and processes (cf. Table II/33) has indicated a "traditional deficit" for the Federal Republic of Germany. The negative balance which had risen to some DM 2 billion by the late 1980s reached a level of DM -2.8 billion in 1991. Since then it has been declining slightly and in 1994, the last year for which data are available, had narrowed to DM -2.2 billion.

Whereas the receipts underlying this balance rose continuously over the last few years, expenditure dropped for the first time since 1992.

By no means, however, does the negative balance suggest that there is a "technological gap" between Germany and other countries. It should also be noted that German patent and licence transactions with foreign countries are characterised by the fact that transfrontier payments are mostly transacted between affiliated companies (cf. Table II/33).

In 1993 59 % of receipts was accounted for by companies with participating interests abroad and 78 % of expenditure by enterprises in Germany in which foreign groups held participations; the corresponding

Figure II/17



*ecu = European currency unit; mean rate of exchange 1993 1 ecu = DM 1.9364 .

Source: European Union (EU)

BMBF, BuFo '96

percentages for 1994 were 63 % and 74 %, respectively.

In reporting on the development of the patent and licence trade the Bundesbank draws attention to the special structural and institutional characteristics of this indicator. The fact that most of the transactions take place between affiliated companies suggests that the firms are anxious to keep technological know-how within the group, thus avoiding competition with their own products and hence losses of their market shares.

As in previous years, companies with participations abroad generated net receipts of DM 1,000 million in 1994 which is considerably up on 1993 (DM +808 million) and at about the same level as in earlier years. The negative balance of companies with foreign participation dropped – as it did in the two previous years – and narrowed to about DM -2.9 billion.

The negative balance of patent and licence transactions of companies in which foreign groups hold participations may be attributable to very different causes. Apart from technological factors, tax-related and economic elements are of special relevance. In most cases, the right to use a patent or a technical process is granted in the form of a manufacturing or marketing licence. The ensuing payments are usually made by subsidiaries to their parent companies. This is why German companies with foreign capital participation have large net expenditure, while German companies with subsidiaries abroad always record high net receipts.

In view of the increase of German direct investment abroad – it now exceeds foreign investment in Germany by far – it may be surprising at first glance that receipts of German groups arising from patent and licence transactions with foreign subsidiaries continued below the corresponding payments made by German subsidiaries to their foreign parent companies (they amounted to only just under 50 %). The Deutsche Bundesbank attributes this to the relatively short time that German enterprises have held assets abroad and to the higher level of foreign direct investment- especially in technology-intensive projects – in Germany. The Bundesbank suggests that due to the different levels of taxation and other fiscal charges in the various countries there may be shifts – especially where affiliated companies are involved – between patent and licence payments on the one hand and the distributions of profits on the other[20]).

Since the balance of payments only covers financial transactions, cases where licences granted are paid for in kind are not included in the licence account. Like payments in patent and licence trade, payments of cash contributions towards financing research and development projects are also subject to different influencing factors.

For many years, Germany had net receipts arising from transfrontier payments for research and development projects which were primarily intended to develop new products and processes and provide scientific consultancy. In 1991 net receipts totalled DM +912 million. In 1992 and 1993 this indicator had a negative balance for the first time (1993: DM -148 million), while in 1994 a surplus was reached again (DM +295 million). This development was the result of stagnating receipts, on the one hand, and substantially increasing expenditure, on the other. In 1994 the trend was reversed, i.e. receipts rose (by just under +4 %) and expenditure dropped quite sharply (by –6 %). It is striking that in 1994 the manufacturing sector had a negative balance again. The reason, as in the past, is the negative balances of the chemical industry and – since 1993 – of the electrical engineering and data processing industries. This means that other sectors, including trade and services, contributed to the recent positive development. A breakdown of transfrontier transactions by most important partner countries highlights the impact of the growing negative balance resulting from cooperation with non-European countries (the USA in particular) as well as the influence of an increasingly positive balance – after substantial former declines – ensuing from coooperation at the European level (also under research and development programmes).

A breakdown of German patent and licence transactions by sectors of economic activity shows that the electrical industry (including data processing), the chemical industry as well as the metal-producing and metal –working industries are still the most important licensors and licensees. In 1994 these three sectors of industry accounted for a good 80 % of receipts and a little less than 67 % of expenditure. Individual trends for these industries, however, are rather divergent and this also applies to other sectors such as trade and services.

In 1994, as in 1993, the chemical industry accounted for the highest proportion of receipts (just over 44 %), while its share in expenditure (19.7 %) was marginally up on 1993 (19.4 %). All in all, receipts in the chemical industry of DM 1,211 million in 1994 compared with expenditure to the tune of DM 978 million.

In the electrical industry the negative 1993 balance remained virtually unchanged in 1994. Its shares in receipts and expenditure increased (to 22.6 % and 41.2 %, respectively), with receipts being substantially higher (21.4 %) and expenditure being lower (47.7 %) than in 1992. In 1994 the negative balance amounted to about DM -1.4 billion.

The balance of the metal-producing and metal-working industries which had slightly picked up in previous years dropped again to DM -81 million in 1994, while in 1993 it had amounted to DM +166 million.

Germany's partner countries in patent and licence transactions are almost exclusively industrialised countries. In 1994 these countries accounted for 82.2 % of receipts and 98.7 % of expenditure. While these figures hardly changed in the period under review, the share of EU countries in receipts accounted for by industrialised countries continued to rise to 47.7 % (compared with 42.1 % in 1991); their share in

[20]) Cf. Monthly Reports of the Deutsche Bundesbank, April 1992.

Table II/33

German*) receipts from and expenditure on patents, inventions and processes, by enterprises holding participating interests abroad, enterprises in which foreigners hold participating interests and other enterprises

– DM million –

Year	Receipts				Expenditure				Balance			
	Total	Enterprises			Total	Enterprises			Total	Enterprises		
		holding participating interests abroad[1]	with foreign participating interests[2]	other enterprises		holding participating interests abroad[1]	with foreign participating interests[2]	other enterprises		holding participating interests abroad[1]	with foreign participating interests[2]	other enterprises
1974	679	635	44	.	1,509	353	1,156	.	– 830	+282	–1,112	.
1975	757	716	41	.	1,793	410	1,383	.	–1,036	+306	–1,342	.
1976	728	654	74	.	1,746	420	1,327	.	–1,018	+234	–1,253	.
1977	778	723	55	.	1,895	462	1,433	.	–1,117	+261	–1,378	.
1978	864	774	90	.	1,937	428	1,510	.	–1,073	+346	–1,420	.
1979	901	820	81	.	1,952	436	1,516	.	–1,051	+384	–1,435	.
1980	1,011	922	89	.	2,079	460	1,620	.	–1,068	+463	–1,531	.
1981	1,095	993	102	.	2,143	536	1,607	.	–1,049	+457	–1,505	.
1982	1,194	1,033	161	.	2,201	524	1,677	.	–1,007	+509	–1,516	.
1983	1,313	1,013	300	.	2,481	436	2,045	.	–1,168	+577	–1,745	.
1984	1,473	1,188	285	.	2,592	527	2,065	.	–1,119	+661	–1,781	.
1985	1,608	1,365	243	:	2,940	589	2,351	.	–1,333	+776	–2,108	.
1986	1,693	1,296	264	134	3,378	539	2,660	180	–1,685	+757	–2,396	– 46
1987	1,792	1,366	262	165	3,398	493	2,729	176	–1,606	+872	–2,467	– 11
1988	1,898	1,552	217	129	3,839	548	3,093	198	–1,941	+1,003	–2,876	– 69
1989	2,110	1,722	199	189	4,084	674	3,164	247	–1,975	+1,048	–2,965	– 58
1990	2,499	1,955	381	163	4,742	793	3,670	279	–2,242	+1,162	–3,288	–116
1991	2,514	1,776	573	166	5,328	780	3,984	564	–2,814	+ 995	–3,411	–399
1992	2,623	1,701	737	185	5,016	704	3,955	357	–2,392	+ 997	–3,217	–172
1993	2,633	1,555	823	255	5,038	747	3,943	347	–2,404	+ 808	–3,120	– 92
1994	2,743	1,732	786	224	4,957	732	3,686	539	–2,214	+1,000	–2,899	–314

*) From July 1990 including the external transactions of the former GDR.

[1]) Enterprises in which there is no major foreign capital interest, whereas they hold major capital interests abroad. Participating interests of more than 20 % (at least 25 % until 1989) and considered to be major interests. Up to 1985, including enterprises without capital ties.

[2]) Enterprises in which there is a major foreign capital interest, i. e. an interest of more than 20 % (at least 25 % until 1989).

Source: Deutsche Bundesbank

Rounding error

expenditure slowed slightly to 19.7 % (compared with 20.6 % in 1993).

In 1994, too, payments focused on the USA (60.6 %) and Switzerland (13.8 %), followed by a wide margin by the Netherlands (5.9 %), France (4.6 %) and Japan (3.7 %). In terms of the book value of their corporate assets, the USA, the Netherlands and Switzerland are at the same time the most important direct investors in Germany[21]).

Comparable with German direct investment abroad, receipts are much more widely distributed among the various regions. In 1994 little more than half (56.1 %) of total receipts came from the USA (24.7 %), Japan (12.0 %), France (7.2 %), Italy (6.2 %) and the UK (6.0 %). While the percentages of EU countries as a whole rose and the Japanese share remained unchanged, the US share declined. The shares of the reform countries (including China) has shrunk over the years since 1990 (1994: 2.8 %) and those of the developing and OPEC countries have hardly changed in recent years.

The USA is still Germany's most important partner country in patent and licence transactions; since 1991 the traditional German deficit in favour of the USA has been slightly more than DM -2 billion. The 1994

[21]) Cf. Statistical Yearbook 1995, p. 697.

deficit in favour of Switzerland is slightly up on 1993, the deficit in favour of the Netherlands dwindled considerably. In its transactions with most industrialised countries, especially Japan, as well as with other groups of countries Germany still has net receipts.

In an international comparison of results it should be taken into account that for statistical and methodological reasons the national data on receipts from and expenditure on patent and licence transactions are not always directly comparable. For instance, copyrights are also included here which is not the case with purely national compilations.

The data available for 1991 and 1993 indicate that among the EU countries only the UK and Sweden had net receipts. The USA still had a very strong positive balance (1993: $ +15.6 billion), Japan's balance was negative ($ –3.3 billion).

Germany's deficit was considerably higher than that of its EU partners (1993: $ –2.4 billion). Among the industrialised countries the Federal Republic of Germany was one of the most important licensees; only Japan had greater expenditure on licences. Among the licensors Germany ranks fifth behind the USA, Japan, the UK and Italy. While in most countries, including Germany, deficits declined, they grew marginally in Finland and Belgium.

The complex interdependencies between payments in patent and licence trade, on the one hand, and economic and technological relations (corporate mergers, joint ventures etc.), on the other, highlight the difficulties involved in interpreting these data. It is impossible to say whether a positive or a negative licence account is better. A positive balance suggests the technological strength of an industry in Germany and the high level of commitment of the business enterprise sector abroad (direct investment), on the other hand expenditure on licences indicates that foreign technological know-how is successfully applied in Germany. It is impossible, though, to make an unequivocal judgement, using the balance of licence payments as an indicator of technological performance[22]).

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22) Cf "Germany's Technological Performance", report submitted to the BMBF by the German Institute for Economic Research (DIW), Bonn 1996.

Part III

R&D funding areas of the Federal Government

Contents

R&D funding priorities of the Federal Government

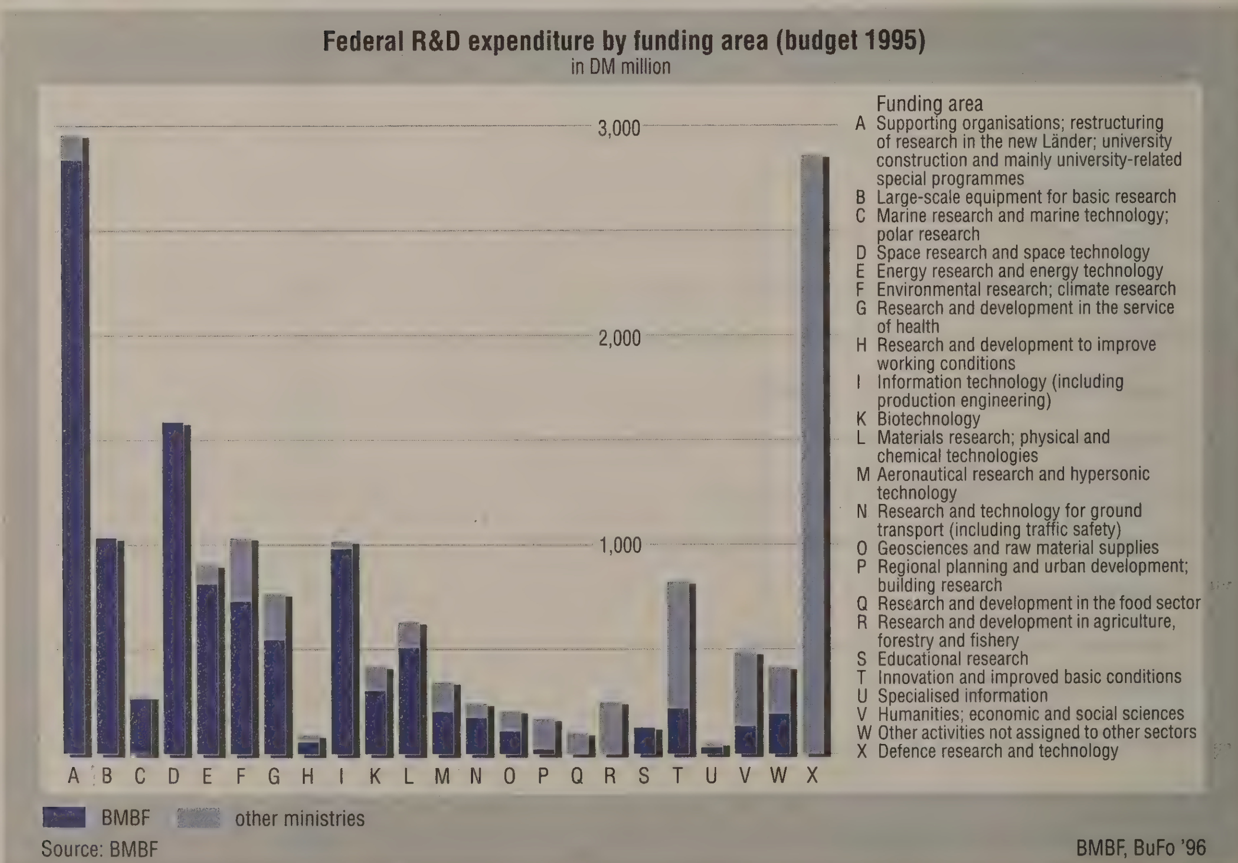
The following part of the Report on Research provides a description of the objectives of the Federal Government's research and technology policy in the various R&D areas. Particular reference will be made to the orientation of the Government's research programme, major results and their realisation, as well as the integration of German R&D into international research activities. Furthermore, the following part will provide an outlook with regard to future research areas. This description is a follow-up to the information provided in the 1993 Report of the Federal Government on Research.

Report is subdivided into subject-related funding areas

The presentation of the Federal Government's R&D activities is subdivided into specific subject-related funding areas and priorities, based on the Federal Government's R&D planning system, irrespective of which federal department finances the activities, and irrespective of whether the funds involved are tied to specific institutions or projects or whether the activities are contributions to international research programmes.

This structure is illustrated by the following diagram (see figure III/1), which provides an overview of the Federal Government's R&D spending (budgeted for 1995) in the various funding areas. Each of the following sections contains a diagram which shows the R&D expenditure in the funding area concerned in the period between 1992 and 1996.

Figure III/1



Funding areas A, B and X cover broader spectrum of research subjects

Some funding areas are not limited to specific subjects but cover a broader spectrum of research subjects: funding area A, for instance, includes the basic funding for the MPG (Max Planck Society), the FhG (Fraunhofer Society) and the DFG (German Research Foundation) – organisations which can autonomously decide on the use of the funds in their various fields of research. The funds allocated for the expansion of

existing higher education institutions and the construction of new ones are generally of benefit to all research disciplines in higher education. Funding area B includes the funding of large-scale equipment needed for basic research whose benefits are shared by a variety of fields of research, including high-energy physics and materials research, as well as biology and medicine. Finally, there is also a particularity with regard to defence research and technology (X): this area includes R&D efforts pursued from a defence perspective in various fields: information technology, materials research, aeronautical and aerospace research, medicine and psychology, as well as the expenditure associated with the development and testing of defence technology.

Research: new knowledge, new technology, new products

The description of the activities in all the various funding areas taken together illustrates *how the Federal Government's research policy objectives are being translated into reality:*

Funding of R&D in the field of *information technology,* for instance – which is one of the BMBF's declared priorities – is oriented towards fostering the transformation to an information society, and annual expenditure on R&D in this field is now greater than DM 1 billion. The BMBF's funding of *biotechnology* R&D during the period under review has helped to create an efficient infrastructure for excellent research, for instance, in the form of genetic research centres. In future, even greater emphasis than in the past will be put on commercial applications of biotechnology. In the field of *health research,* groups of clinical researchers will combine basic medical research with clinical research topics. One of the objectives of *environmental research* – which is focused on the principle of sustainability – will be to integrate environmental protection into production processes and products. *Space research* is more and more directly related to applications with subjects such as Earth observation; the European contribution towards the international space station has taken on concrete forms. In the fields of *marine, polar, climate and geoscientific research,* Germany is making important contributions to global research programmes. Many funding areas are characterised by collaborative projects in which university and non-university institutions cooperate by dividing research responsibilities amongst themselves. This helps achieve an *intensive transfer of know-how* and a rapid market introduction of new findings.

Coordination of the federal ministries' R&D activities

Other ministries – in addition to the BMBF – are also involved in research activities in a number of funding areas, some of them to a considerable extent. This so-called *departmental research* (see box) is primarily aimed at meeting the research requirements of specific ministries. However, such research can also help to broaden the general scope of knowledge, e. g. in projects carried out by the Federal Ministry of Health to investigate the causes of specific diseases. It goes without saying that there is overlapping between the R&D activities of the various ministries. In the interest of research efficiency and in order to avoid duplication, it is therefore necessary to coordinate the research efforts made by the various ministries involved. *The Federal Government's Coordination Concept* has been developed for this reason. Its primary objective is to coordinate the contents of research activities, which also includes the development of cooperative research programmes for several ministries (government programmes). Such programmes are currently in operation in several fields such as health research, work and technology, and aeronautical research. A cooperative environmental research programme involving the participation of several ministries is currently being developed; furthermore, preparations are being made to develop additional programmes in other fields (e. g. building and home living, specialised information). In addition, there is a continuous

Research funding and departmental research

The purpose of the BMBF's *research funding and technology promotion* is to help broaden the generally available body of knowledge and to promote scientific and technological progress in selected fields. To this end, the BMBF tackles new research subjects and defines their scope by means of research programmes, and invites tenders. Interested researchers or groups of researchers from science and industry apply for funding by submitting project proposals. All projects to be funded directly are published[1]). In addition, the research reports are also available to interested parties[2]).

Departmental research is aimed at obtaining scientific findings which are directly related to the fields of activity of a given ministry or department. Such findings are used as a basis for decision-making to ensure proper execution of departmental functions. If the general status of knowledge is not sufficient for this purpose, the necessary research activities will be primarily carried out by federal institutions. In the area of responsibility of the Federal Ministry of Transport, for instance, the technical rules for the expansion of the federal network of roads and waterways are continuously being optimised; the *Federal Institute of Physics and Metrology* – which is subordinated to the Federal Ministry of Economics – carries out a considerable amount of research aimed at continuously optimising the status of public metrology and testing, in response to increasingly demanding requirements. If research is conducted by external institutions, the findings to be scrutinised are exactly described, and contracts for the corresponding research projects are invariably awarded on the basis of public tenders.

1) BMBF funding catalogue (published annually), Cologne, Verlag TÜV Rheinland; FORKAT database, available from STN International, Karlsruhe.
2) Technische Informationsbibliothek (TIB), Hanover.

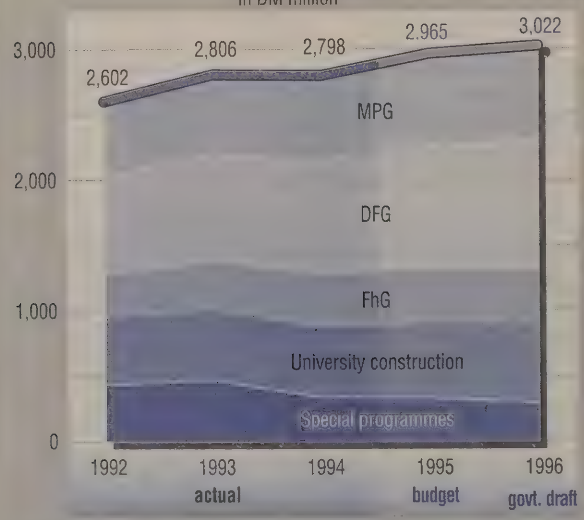
process of coordination at various working levels, which in some cases has been institutionalised (e. g. in the form of interdepartmental coordination bodies for health research and for aeronautical research). On the other hand, there is a set of tried and tested instruments for *interdepartmental coordination by means of information.* These instruments range from aggregated accounts of the research activities of a given ministry (including the resources used) to the coordination of specific projects, just prior to the decision in favour of their implementation ('early coordination'). The Interdepartmental Committee on Science and Research, which is composed of the various ministries' representatives in charge of research, monitors the coordination activities of the ministries.

1. Supporting organisations; university construction and mainly university-related special programmes
(Funding area A)

Good general conditions for science and research

Science and research can only prosper in an attractive environment which can also stand up to international comparison. This includes the stock of equipment available at higher education institutions and other research institutions, as well as good educational conditions for young academics. For this reason, the Federal and Länder governments jointly provide funding to research organisations – cross-disciplinary and primarily as basic funding; this also applies to the co-operative task of university construction. It is thus possible to cover the broad spectrum of scientific activities which is indispensable for an industrialised nation with a cultural awareness.

Federal R&D expediture on supporting organisations; restructuring of research in the new Länder; university construction and mainly university-related special programmes
in DM million



Source: BMBF BuFo '96

Together with the Länder governments, the Federal Government provides funding for the two large research organisations in Germany: the *Max Planck Society* (MPG) and the *Fraunhofer Society* (FhG). In fact, the Federal Government accounts for 50 % of the basic funding of the MPG, and for 90 % of the basic funding of the FhG. While the MPG carries out independent basic research in new fields which are important for the future but which have not yet been established at universities, the FhG's activities are focused on applied research, in particular the practical application of the results of basic research.

The *German Research Foundation (DFG)* is also funded jointly by the Federal and Länder governments. The DFG is a self-governed scientific organisation which provides funding to individual scientists and to groups of scientists from all disciplines under a variety of programmes. The Federal Government's contribution to the funding of these programmes amounts to 50 % or more. The DFG primarily supports research at higher education institutions. In addition to the MPG and the FhG, the DFG plays a major role in strengthening and integrating research efforts made in Germany's new Länder, and in promoting international cooperation.

Research and support organisations as well as university construction funded jointly by the Federal and Länder governments

The *building and extension of higher education institutions* including university hospitals is also a task tackled jointly by the Federal and Länder governments. The fundamental objective in this context is to adapt the higher education institutions – which are an integral part of the overall system of education and research – to national and international requirements. This means that in this framework, research funding priorities are also supported at universities, while taking into consideration non-university research institutions as well.

In addition, there are *special programmes* conducted by the Federal Government for limited periods of time in agreement with the Länder governments in order to support universities in fields which – because of their particular importance or their exposure to particular burdens – require rapid and disproportionately high funding. These special programmes are of use both to teaching and to research (see box). In the period between 1991 and 1996, some emphases were placed on restructuring higher education and research in Germany's new Länder.

The Special Programmes at a glance

Special University Programme I (HSP I)

Successfully completed in 1995: aimed at increasing training capacities in particularly crowded courses of study, and establishing new study courses.

Special University Programme II (HSP II)

Focused on Germany's old Länder: aimed at promoting junior scientists and women in science; at supporting Fachhochschulen; and at giving more weight to the European dimension.

University Renewal Programme (HEP)

Focused on Germany's new Länder: objectives are largely the same as those of HSP II; in addition, aimed at funding the creation of new university chairs; supporting distance study courses (by correspondence); funding investment measures; integrating former staff of the Academy of Sciences (Integration Programme for Scientists); and upgrading skills and qualifications.

DFG Programmes

Supporting highly qualified young scientists: post-doctoral programme, post-graduate studies, front-line research (Leibniz programme), Heisenberg programme.

2. Large-scale equipment for basic research (Funding area B)

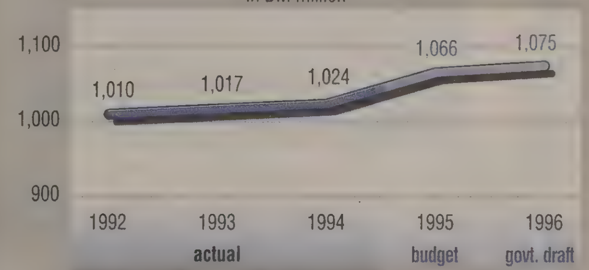
Cutting-edge results of basic research

For high-energy physics, it is a major breakthrough: By means of complex tests using large-scale equipment, it has been possible to provide *experimental* support for the so-called standard model of *theoretical* physics. European and also German laboratories had a major share in this success.

Not least because of such results, German basic research enjoys high esteem at international level. Since the early 1980s, the stock of equipment – in particular large-scale equipment – has been considerably expanded or renewed. Today, scientists have at their disposal excellent experimental equipment for research on condensed matter and for front-line research in the fields of nuclear and particle physics as well as in astronomy and astrophysics.

The BMBF's funding of research using large-scale equipment is focused on specific priority topics, primarily large accelerators, neutron and synchrotron sources, as well as observatories and telescopes.

Federal R&D expenditure on large-scale equipment for basic research
in DM million



Source: BMBF BuFo '96

The largest research instrument in Germany is HERA, the world's only electron-proton storage ring system, which is based at DESY, the national research centre in Hamburg. Since the end of 1992, HERA has been available for high-energy physics experiments (see box).

In the past few years, two other large research instruments have become operational: the European Synchrotron Radiation Facility (ESRF) at Grenoble and the Cooler Synchrotron (COSY) at Jülich. Furthermore, after the modernisation of the ILL reactor and the repair of the FRJ-2 reactor at the Jülich national research centre both reactors went back into operation. In addition, the construction of the new Berlin synchrotron radiation source at Adlershof (BESSY II) and the construction of the Very Large Telescope (VLT) in Chile are making rapid progress. In 1994, a decision of principle was taken at CERN to build the Large Hadron Collider (LHC).

HERA: DESY's flagship of large accelerators

DESY has a total of 9 accelerator systems, some of which are equipped with superconducting components (total acceleration length: 15.7 kilometres). Every year, 1,400 researchers from over 90 German universities and approximately 1,200 foreign scientists from over 33 countries use these accelerators for experiments in the fields of high-energy physics and the application of synchrotron radiation. The 'flagship' of DESY's stock of large-scale equipment is HERA – *(Hadron Electron Ring Accelerator).* The construction cost of HERA amounted to DM 1.37 billion, of which 22 % was paid by foreign institutes in an unprecedented and exemplary international cooperative exercise ('HERA model'). HERA consists of a 6.34 km ring tunnel which is located at a depth of between 10 and 30 metres. After pre-acceleration, electrons and protons are stored in two separate rings and then brought to collide in four interaction zones. The investigation of the processes occurring during these collisions has already provided many insights (e. g. into the surprisingly complex internal structure of protons) and will probably lead to new findings about the structure of matter.

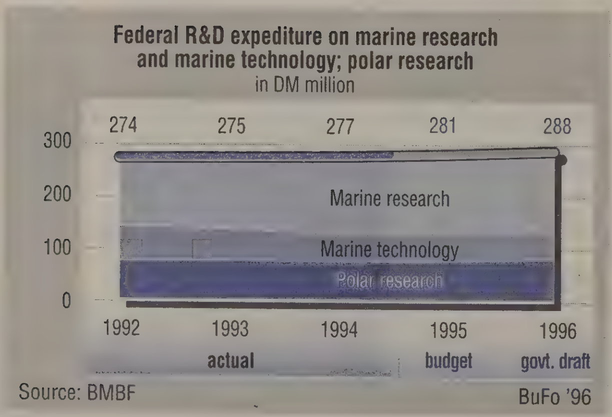
The construction, operation and use of such large-scale research equipment increasingly requires international division of labour. In the past few years, Germany's policy in the field of large-scale equipment has played a major role in creating the world's best working conditions in Europe for studying the structure and dynamic properties of matter.

Since Germany is a country with a limited supply of raw materials, it can only safeguard its standard of living by being a top performer in the fields of science, technology and industry. The efforts made in basic research are therefore an investment in the future.

3. Marine research and marine technology; polar research
(Funding area C)

New findings about the climate

Approximately 70 % of the Earth's surface area is covered by oceans. For this reason, investigations into marine ecosystems and interactions between the oceans and the atmosphere are of fundamental importance for a large number of fields of science. The oceans play a key role, for instance, in the global climate. In this context, polar research has also provided important findings.



In 1993, the Federal Government initiated a new *Marine Research Programme* which is focused on three issues: the role of the ocean as a climate factor; the role of the ocean as an ecosystem; and the role of the ocean as a source of resources. With a view to potential climate change, the purpose of the programme is to study various marine factors such as sea level changes and their impact on coastal regions in order to be able to make long-term predictions. The findings obtained to date by means of numerical simulation models are not yet precise enough for this purpose. For this reason, a *Global Ocean Observing System* (GOOS) is currently being prepared to permit global monitoring of marine events and processes which are relevant to the climate.

In addition, German marine scientists participate in all major international marine research programmes, including those of the *World Climate Research Programme* (WCRP) and the *International Geosphere/Biosphere Programme* (IGBP) and the *Ocean Drilling Programme* (ODP). In this context, particular importance is attached to the World Ocean Circulation Experiment (WOCE) and the Joint Global Ocean Flux Study (JGOFS).

Environmental conditions in the Baltic Sea studied in cooperation with the other Baltic Sea countries

Germany's research efforts in the field of the marine environment are focused on two regions: the North Sea and the Baltic Sea. In 1994, Germany set up a *cooperative research project* called *KUSTOS* (KUSTOS stands for *Küstennahe Stoff- und Energieflüsse – der Übergang Land-Meer in der südlichen Nordsee,* i. e. Near-Shore Flows of Substances and Energy: The Land/Sea Interface in the Southern Region of the North Sea). The purpose of the KUSTOS project is to study exchange processes between the tideland areas and the open North Sea. Since Germany's unification, there has been growing interest in the environmental conditions prevailing in the

Baltic Sea. In 1994, the *BMBF* published a *Baltic Sea Research Concept,* which provided an overview of current activities in this area and defined the research priorities for the following years. This concept was also aimed at achieving closer cooperation with other European countries, in particular the Scandinavian and the Baltic countries.

State-of-the-art research vessels

German marine and polar scientists have access to first-rate research vessels to help them conduct their studies:

- The 'Meteor' is used for global basic research on the high seas. The vessel's operating costs are shared between the BMBF (30 %) and the DFG (70 %).
- The 'Polarstern' is used not only as a research platform but also as a supply and disposal vessel for field camps and stations in the polar regions. Since her commissioning in 1982, the 'Polarstern' has been on twelve Antarctic expeditions. Interface studies conducted west of Spitzbergen during the 'Polarstern's' first Arctic expedition, which began in spring 1993, dealt with cold waves and heat exchanger in the ice edge zone.
- Other research vessels are used to carry out specific projects or to deal with certain regional issues. The 'Sonne', for instance, is a research vessel which is chartered for specific expeditions.

In addition to funding specific projects, the Federal Government also makes major contributions to the basic funding of scientific institutions. The most important marine research institutes in Germany include the 'Blue List' institutes, the *Helgoland Biological Institute,* the *Federal Research Centre for Fisheries* in Hamburg and the *Alfred Wegener Institute for Polar and Marine Research* (AWI), which is funded jointly by the Federal Government and the governments of Bremen and Brandenburg. The results of the AWI's research, which is focused on polar regions, provide insights into the ocean-atmosphere-cryosphere system and into maritime ecology.

General political climate for polar research has improved

Polar research provides a wide variety of useful information, including valuable insights into past climate conditions and climate change. The considerable progress achieved in the field of scientific research on these regions has been spurred by two developments: First of all, the technical prerequisites have substantially improved; and secondly, the general political climate has also improved. As a result, major restrictions which used to be imposed on research in the Arctic region no longer apply today. In Antarctica, science has benefited from the Antarctic Treaty, which the Federal Republic of Germany has successfully helped to develop since 1979. Consequently, the Federal Government has considerably stepped up its funding of polar research.

The third priority in this funding area is *marine technology.* In its new *Research Concept 1994–1998,* the BMBF has included the wide variety of recommendations made by governmental and industrial organisations such as the 'Maritime Industries Forum' and the 'Deutsches Maritimes Industrieforum'. With this new concept, the Federal Government has also responded to the reorganisation of the maritime industry in the new Länder and to the growing traffic volume in the European Economic Area.

4. Space research and space technology
(Funding area D)

New priorities in German and international space research

In the past few years, the objectives and the substance of German space research policy have evolved continuously, which has also led to the definition of new priorities in the field of international cooperation by increasingly involving Russia and Japan. The general conditions for space research have become much clearer, in particular in Europe, because the European Space Agency (ESA) has taken some fundamental decisions after long and intensive consultations at ministerial level.

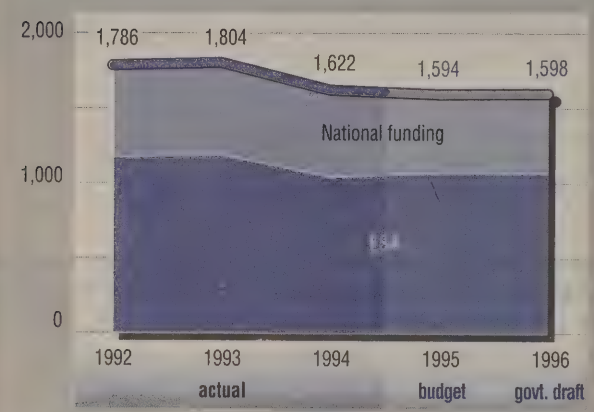
In October 1995, the ESA conference of ministers in Toulouse took some future-oriented decisions, due not least to Franco-German solidarity. Among other things, the ministers decided that Europe would participate in the planned International Space Station. The basis of the European commitment to this project will be the use of the laboratory module COF (Columbus Orbital Facility) and the ARIANE 5/ATV (Automated Transfer Vehicle). In negotiations with the American side, it was possi-

ble to resolve the question of the distribution of the common operation costs, which had already been discussed at the conference of ministers in Granada (1992). As a result of the negotiations, Europe will make its contribution by supplying certain services, in particular using the ARIANE 5 and the ATV for supply flights to the space station.

ARIANE provides independent space access for Europe

At the Toulouse conference, the ministers also emphasised that Europe should have its own access to space. In addition, the ministers adopted three complementary programmes (ARIANE 5 Evolution, ARIANE 5 Infrastructure, and ARTA/ARIANE 5) for the implementation of the ARIANE 5 project.

Federal R&D expediture on space research and space technology
in DM million



Source: BMBF BuFo '96

Based on the objectives defined by the cabinet's space committee on 27 June 1990, the German Federal Government also set new priorities in its national programme, making major efforts to integrate the scientific and industrial capabilities in the new Länder, to intensify cooperation with Russia and Japan, and to increase capacities in the field of Earth observation – thereby supplementing the ESA programme.

The major substantive objectives pursued by Germany in the field of space research have not changed. The fundamental purpose of this research is to obtain scientific findings about the Earth and outer space. In addition, Germany hopes to create incentives for technological progress and to strengthen the efficiency of German industry. However, there are also practical benefits which space research is expected to provide. These include finding solutions to environmental issues by means of satellite-based Earth observation, and improving public and commercial infrastructure – for instance, in the telecommunications sector.

Satellites used for environmental research and communication engineering, 'satellite-based astronomy'

In recent years, German research efforts have produced leading-edge results which attracted international attention. In the field of *Earth-oriented research,* the second ESA Remote Sensing Satellite ERS-2 (identical in design with ERS-1, launched in July 1991) was launched and successfully put into operation in April 1995. Both satellites were designed and built under the leadership of German industry. ERS is an all-weather system whose active microwave instruments make it possible to carry out all measurements irrespective of the presence of daylight. In addition, GOME – the ozone measuring device installed on ERS-2 – permits precise global monitoring of stratospheric ozone concentrations. In the field of *extraterrestrial research,* the predominant event is the continuing monitoring of X-ray and EUV radiation sources in outer space by the German X-ray satellite ROSAT. Particular mention should also be made of the Shuttle missions with the ASTRO-SPAS re-usable platform, which was used in 1993 to transport the astronomy telescope ORFEUS into space and in 1994 to transport the atmospheric monitoring instrument CRISTA to its destination. The important role played by German research in this field is also corroborated by Germany's successful participation in NASA's Gamma Ray Observatory (GRO).

EUROMIR

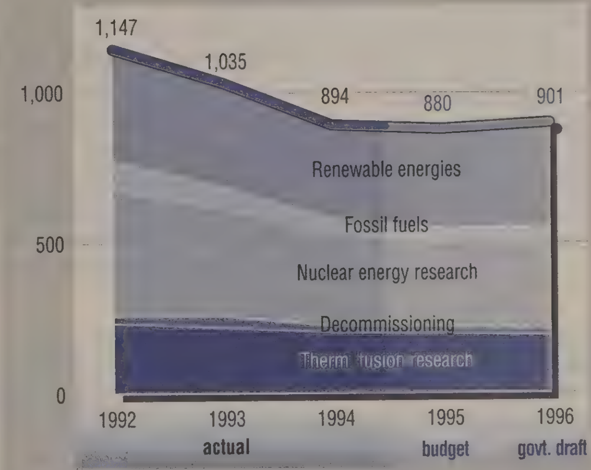
In 1994, the Russian space station was used for a 30-day space mission (EUROMIR '94), which had been commissioned by ESA. The German astronaut Dr Ulf Merbold carried out experiments on board for which he could use part of the equipment from the German MIR '92 mission which had remained on board the space station. Thomas Reiter – also a German astronaut – was selected for ESA's second MIR mission (EUROMIR '95), which was initiated in 1995. Initially, the flight was supposed to last 135 days, but its duration was then extended by 45 days. Another German MIR space mission is scheduled to take place before the end of 1996.

5. Energy research and energy technology
(Funding area E)

Promoting an ecologically sustainable energy supply system

One of the elementary prerequisites for a sustainable national economy is a reliable supply of energy produced at low cost and in an environmentally sound manner. However, the provision and use of energy may cause environmental problems. Hence, the Federal Government's research funding is focused on both the economic and the ecological importance of the energy sector.

Federal R&D expediture on energy research and energy technology
in DM million



Source: BMBF

BuFo '96

With its *Fourth Energy Research Programme,* which will be initiated in 1996, the Federal Government wants to lay the technological foundations for a sustainable reduction of energy-related adverse effects on the environment and the climate. A wide variety of research activities will be carried out to develop new, highly innovative products and processes. Hence, this programme also helps to preserve Germany's attractiveness as a centre of technology. A number of projects will be carried out in cooperation with partners from other countries.

The programme focuses on the following research areas:

- Reducing energy consumption; this can be achieved by means of more efficient energy conversion and energy use, and by optimising the use of secondary energy sources.
- Opening up long-term energy sources which do not involve CO_2 emissions; this can be achieved by promoting the use of renewable energy sources, continuing to use nuclear energy (reactor safety, radiation protection, final radioactive waste disposal, and dismantling nuclear power plants), and optimising thermonuclear fusion.
- Tackling interdisciplinary issues such as systems analysis, information processing, and the removal of innovation barriers.

Fourth Energy Research Programme: protecting the environment, while at the same time promoting Germany's leading role in technology

Using coal as a fuel: identifying development potentials

Increasing the efficiency of coal-fired power stations

According to the Federal Government's declared intention, coal will continue to play a major role in Germany's energy supply. At present, close to 30 % of Germany's primary energy consumption and 56 % of the country's electricity generation is covered by coal. Research funding in this field is primarily aimed at creating the conditions which will help make environmentally sound and cost-effective use of fossil fuels (i. e. coal, gas and oil). By introducing new power plant and combustion technologies, it is possible to achieve substantial improvements with regard to the efficiency of energy conversion, while at the same time reducing CO_2 emissions and fuel consumption. The objective to be achieved within the next 15 or 20 years is to increase the efficiency of combined-cycle, gas-fired and steam-generating power stations to 55 % (average power station efficiency is currently approximately 36 %). The progress made to date makes it possible already today to achieve efficiency levels of approximately 42 % by retrofitting environmentally sound and performance-enhancing technology in existing power stations and by installing such technology from the very beginning when building new power plants.

In this context, important findings were obtained from the two cooperative projects called 'High-Temperature Gas Turbine' and 'TECFLAM'. Other research activities helped to improve the atmospheric circulating fluidised-bed firing process – in particular for small power stations – by means of a technology which has now found international market acceptance.

Renewable energy: developing new technologies

Renewable energy sources such as hydropower, solar radiation, wind, biomass, geothermal energy and ambient heat help conserve scarce resources and reduce adverse effects on the air, the water, the soil and the climate. Theoretically speaking, the energy potential of the renewable energy sources is substantial. However, making cost-effective use of these energy sources is currently possible to a limited extent only and takes a long time. At present, renewable energy sources and waste incineration cover only about 2.5 % of the primary energy consumption in Germany. The BMBF has now decided to change this situation by providing substantial funds to promote research in this field (see box). In 1996, close to DM 339 million has been earmarked for research on renewable energy sources and efficient energy use.

Using less energy for heating and manufacturing

Over 80 % of the energy needed for space heating in households is produced by means of fossil fuels. However, the CO_2 emissions associated with the use of these fuels have an adverse climate impact. Effective countermeasures include low-energy heating technologies, improved thermal insulation, as well as the energy-oriented modernisation of industrially constructed residential buildings in the new Länder and the construction of new buildings with optimised solar technology. Another option for the substitution of CO_2-releasing energy sources in the field of space heating is the use of solar energy and biomass. The technologies, products and processes required for this purpose are funded by the BMBF under its 'Solar thermal power 2000' programme and by the Federal Ministry of Food, Agriculture and Forestry with a programme entitled 'Grants for the promotion of renewable resources'. This programme includes projects which are aimed at studying the long-term behaviour of thermal solar installations and short-range solar heat.

In the interest of energy conservation and efficient energy use, the BMBF provides funding for cross-sectoral processes (unit operation) such as increased recycling of materials or the use of catalysts and various drying technologies for use in the manufacturing sector. In this context, a wide variety of generic technologies are supported, e. g. in the fields of compressed-air generation, compression, pumping technology and air conditioning.

Federal R&D funding for renewable energy sources

- 'Photovoltaics 2005' is a 10-year programme which is designed to prepare the ground for increasing the use of photovoltaics by helping to reduce the production costs of photovoltaic systems and by more extensive testing of photovoltaic systems in housing estates and on industrial buildings. As many as 2,100 photovoltaic systems have already received funding in the framework of the '2,000 Roofs Programme' introduced by the Federal and Länder governments.
- In cooperation with developing countries and newly industrialised countries, innovative wind and solar energy technologies are subjected to large-scale tests under the 'ELDORADO Wind' and 'ELDORADO Sun' programmes; in addition, funding is provided for small-scale photovoltaic systems and solar cooking, drying and cooling technologies.
- The results of the '250 MW Wind' demonstration programme, which has been almost completed, are evaluated and applied by means of scientific monitoring and evaluation programmes. In many cases, wind power is used cost-effectively due to improved technology.
- In order to make progress in the use of geothermal energy by means of the 'Hot Dry Rock Technology', the BMBF is participating in a research project in Soultz-sous-Forêt (Alsace/France), which is conducted within the EU framework. If the current R&D activities produce promising results, a demonstration project will be carried out at the same location.
- Environmentally sound combustion and gasification technologies are being developed to use biomass and waste materials for energy production purposes.

Federal Government continues to rely on the use of safe nuclear energy

Nuclear energy: necessary and justifiable

The Federal Government feels that it is justifiable to use nuclear energy, given Germany's high safety standards. In order to support and further improve these standards, the German Government funds research activities in the fields of nuclear reactor safety, final waste disposal and radiation protection. For Germany's position as an industrialised nation, nuclear energy is an important element of the country's energy and environmental policies, especially since the use of nuclear energy helps avoid annual emissions of up to 150 million tonnes of CO_2 in the Federal Republic of Germany alone. For many years, approximately 30 % of Germany's electricity has been produced in nuclear power plants. This corresponds to approximately 10 % of the country's primary energy consumption.

The precondition for responsible use of nuclear energy is the safe final disposal of nuclear waste. Hence, final disposal is also one of the research areas funded by the BMBF. The research project 'Direct final disposal', which was completed at the end of 1995, demonstrated that direct final disposal is technically feasible. In addition, the project – carried out in co-operation with EURATOM and the IAEO – helped develop instruments and processes for monitoring fissile material, e. g. special-purpose sealing systems for the containment of radioactive substances.

The safety of nuclear energy is also supported by activities in the field of radiation protection. There were a variety of R&D projects which were aimed at

– analysing natural and civilisation-induced exposure to radiation,

– studying radon concentrations in residential buildings,

– identifying health risks associated with radiation exposure during uranium mining,

– improving measuring devices, dosimeter systems and accident prevention.

Thermonuclear fusion: energy source of the future?

Opening up another energy source whose potential is almost inexhaustible and which does not cause any CO2 emissions – this will be one of the great challenges in the next few decades. However, this other energy source – which is thermonuclear fusion – is a highly complicated field of research in which progress can be made only in small experimental steps. It is not very likely that there will be a commercial thermonuclear fusion reactor before the middle of the next century.

In 1996, the BMBF will provide funds amounting to approximately DM 171 million for thermonuclear research in Germany. In addition, Germany's federal states will contribute DM 17 million and EURATOM DM 65 million. German thermonuclear fusion research is embedded in the cooperative European Thermonuclear Fusion Research Programme. The Max Planck Institute for Plasma Physics in Garching, as well as the two national research centres in Jülich and in Karlsruhe are conducting studies on plasma physics and carrying out technical development activities using large-scale test facilities. The results obtained to date have met with international acclaim. This applies, for instance, to the further development of the stellarator principle, which is based on the assumption of continuously operating plasma. The next generation of the stellarator is already being planned: The purpose of Wendelstein W 7 X – a stellarator with superconductive magnets which will be installed in Greifswald – is to demonstrate the suitability of the stellarator principle for thermonuclear fusion reactors.

6. Environmental research; climate research (Funding area F)

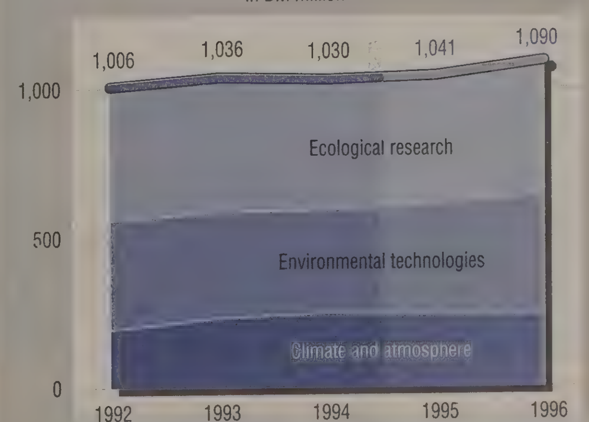
Research for the environment – research for humanity

The purpose of environmental and climate research is to show policy-makers, industry and society where human interventions in natural ecosystems pose a threat and how these threats can be avoided. This requires better a understanding of interactions. Major prerequisites for successful research and effective policies include more profound understanding of systems – e. g. in the field of ecological research – and insights into the global scope of many processes – e. g. in the field of climate research. In many cases, it has been possible to avoid environmental hazards from the outset and to conserve resources by applying technologies which integrate environmental protection into production processes and products.

In the past few years, new findings on the environment and more environmentally sound behaviour based on these findings have led to considerable improvements in Germany's environmental situation.

At the United Nations Conference on Environment and Development which was held in Rio de Janeiro in June 1992, the international community made a commitment to pursue the objective of 'sustainable development'. For the time being, however, this objective merely indicates the *general thrust of activities* to be carried out. What is needed is a systematic search for sustainable development. To this end, it

Federal R&D expediture on environmental research; climate research
in DM million



Source: BMBF
BuFo '96

Defining environmental objectives: creating scope for innovations

will be necessary to define environmental objectives. The purpose of environmental research is to make active contributions to the definition of environmental objectives and to identify options and needs for action – together with other disciplines – in order to attain these objectives.

The Federal Government is called upon to shape the general setting so as to encourage competition during the search for the best solution in each field to attain these objectives, and so as to create incentives for innovations which will foster sustainable development. The use of market economy instruments and the increasing internalisation of external costs to enforce the 'polluter pays' principle will play an important role in this context.

The Federal Government's Environmental Research Programme

The Federal Government's *Environmental Research Programme,* which is in the process of being drawn up, specifies three key areas of research: participating in defining the environmental objectives, creating new technologies and action strategies for sustainable development, and greater emphasis on accelerating the practical application of research findings.

These three objectives are also the guidelines for the BMBF's funding policy in this area, which is focused on three major research priorities:

- ecological research,
- research in the field of environmental technology, and
- climate and atmospheric research.

Preserving the balance of nature

Using natural landscapes without destroying them

The purpose of *ecological research* is to provide the information which is necessary to know where and when the renewal and development potential of ecosystems is jeopardised by human interventions in nature.

Priorities of ecological research

Urban Ecology funding concept: Five cooperative projects are aimed at developing models for sustainable local water management in the cities of Frankfurt/Main, Dresden, Dortmund, Zwickau, Freiburg, Schwerin, Bremen, Halle, Munich and Leipzig; in addition, these projects are designed to investigate ways of controlling ecologically sustainable mobility in urban regions.

Rainfall-induced water pollution due to runoff from urban built-up areas (NIEDERSCHLAG): A cooperative BMBF project carried out in several phases by the University of Karlsruhe together with scientists from the universities of Dresden, Essen, Hanover, Kaiserslautern and Stuttgart. The project has already produced preliminary results.

Funding activity *'Modernisation and ecological design of landscapes in lignite mining areas in the new Länder':* The purpose of this project is to reintegrate into the landscape a total of 189 abandoned open-cast mines and worked-out open cuts and to prepare them for new ecologically sustainable and economically viable uses. In addition, the BMBF also provides funding for cleaning up old deposits in lignite mining fields.

'Agricultural landscape research': This long-term project, which was initiated in 1993 and is scheduled to run for 15 years, is carried out by the FAM (Forschungsverbund Agraröksysteme München – Agrarian ecosystems research association); it is composed of 52 specific projects which are coordinated with each other in terms of the subjects covered. One of the objectives of the project is to study the effects of various cultivation and management methods on area productivity.

Funding activity *'Watercourses':* Many watercourses have lost their natural structures because of regulation, barrages and weirs. The BMBF funds R&D activities aimed at restoring the natural structures and permitting environmentally sound use of water resources and surrounding areas. Between 1991 and 1996, ecological remediation concepts were developed for six rivers (Vils, Warnow, Hunte, Lahn, Ilm, Stör) in the framework of the BMBF's funding activities; these concepts are now used as a basis for renaturalisation activities of the various Länder concerned.

In order to identify options for designing landscapes in tune with nature, and to develop strategies for the sustainable use of landscapes, the BMBF provides funding for *ecosystem research* and in particular for R&D in the following specific fields: urban industrial landscapes, silvicultural and agricultural landscapes, as well as riverine and lake landscapes (see box). The objective of this research is to define the conditions for long-term use of terrestrial and limnic ecosystems, which will help to preserve natural dynamics. The Federal Government's environmental samples bank which is currently being built up will help perform retrospective studies of ecotoxicological and toxicological interdependencies.

Progress has been achieved in particular in the field of research into forest ecosystems. Studies have shown, for instance, that while forests absorb large amounts of atmospheric nitrogen compounds, they release them again as soon as their full absorption capacity is reached. As a result, there may be increased pollution due to nitrate being washed out into the groundwater.

In the framework of ecological research, the BMBF also provides funding for research into new, holistic *biotope and species protection* concepts and new sustainable management strategies. Another funding priority is the analysis of potential *health risks due to environmental pollution.*

High-tech for environmental protection

Environmental protection is a societal concern which is reflected in the BMBF's entire research policy. Environmental aspects are major criteria in taking decisions on research funding. When it comes to funding research in the field of environmental technology, the direct primary objective is environmental protection. The purpose of research in this field is to develop and use innovative methods and processes which will help, where possible, to avoid adverse man-made effects on the environment – or at least to curb them – and to avert potential hazards from existing environmental pollution.

Integrating environmental protection into production processes

While in the past few decades environmental protection has been mainly focused on the development and successful use of end-of-the-pipe remedial technology (which, however, has entailed additional costs), today's key impetus comes from the idea of integrating environmental protection into production.

In many cases, developing environmental protection measures which are integrated into the production process provides a better opportunity to improve both ecological and economic conditions alike. This new development was reflected by a new funding programme called PIUS (which stands for 'Production-Integrated Environmental Protection; see box) which was initiated in 1994.

PIUS

PIUS *(Produkt- und Produktionsintegrierter Umweltschutz)* is a technology-oriented research funding programme which is aimed at optimising production processes and products as well as at developing full recycling solutions, which means that from the outset:

- product-related and production-induced emissions (e.g. waste gas, waste water, solid waste) are avoided or reduced as much as possible, and
- the use of resources (raw materials, energy) during the production, use and disposal of products is minimised.

The objective pursued by the Federal Government with this programme is the effective decoupling of economic growth from environmental pollution.

The first few projects to be funded under this programme include a process for residue-free and resource-conserving production of cement and the recycling of what is currently hazardous waste from metal-working processes.

Another funding priority in the field of environmental technology is *waste avoidance and waste disposal.* Research in this field has achieved considerable success. One of the many success stories is a cooperative project entitled 'New flotation processes designed to increase the recycling rate of waste paper'. The results produced by this project include the development of a new flotation process which removes certain printing inks more effectively ('de-inking'), as well as more easily 'de-inkable' water-based inks.

In order to cope with legacy problems, the Federal Government is funding the development and testing of effective exploration and assessment methods as well as safety and remedial measures.

Improvement of water quality in stagnant and running water bodies

Furthermore, the Federal Government funds important projects in the field of *water research and technology.* This includes a cooperative project entitled 'Dams and lakes', which deals with drinking water supply from stagnant water resources in the new Länder. Under a pilot project entitled 'Elbe 2000', scientists analyse the pollution levels of this large river and devise ecologically sustainable clean-up strategies. Another priority in this context is to develop remedial technologies for leaky sewers. According to estimates, over one-fifth of West Germany's sewerage system – which has a total length of 300,000 kilometres – is damaged; in the new Länder, over half of all sewers are believed to be defective.

Research aimed at understanding climate change

The BMBF's activities in the third major funding area – *climate and atmospheric research* – are based on the realisation that many human interventions in natural ecosystems cannot be regionally limited. Instead, threats such as the destruction of the vital ozone layer and climate change caused by greenhouse gases are global challenges.

Climate: global impact of regional human interventions

The Federal Government has paid heed to this realisation. In 1992, it established the *German Advisory Council on Global Change (WBGU)* which is supervised jointly by the BMBF and the Federal Ministry for the Environment, Nature Protection and Nuclear Safety (BMU). The WBGU presents annual reports on global cli-

mate change and its effects. At the first meeting of the parties to the Framework Climate Convention in Berlin in 1995, the WBGU presented a special report in which it developed a scenario for reducing global CO2 emissions in the next few decades, taking into consideration both ecological and economic aspects.

Deeper understanding of atmospheric processes

Since 1985, one of the funding priorities has been *research into physico-chemical processes in the atmosphere.* The purpose of this research is to study the behaviour of pollutants in the lower strata of the atmosphere (troposphere). Under the EUREKA project EUROTRAC, the BMBF spent a total of approximately DM 90 million to fund about 100 German projects. The purpose of these projects was to study transboundary air pollution – by means of monitoring networks which extended from Tenerife to Spitzbergen, and by means of laboratory studies and computer simulations. In addition, the BMBF provided approximately DM 27 million in funds for a supporting scientific programme (SANA) designed to remedy the atmosphere above the new Länder.

Another funding priority is *stratospheric research.* The main purpose of the second phase of the *Ozone Research Programme* will be to analyse hitherto unresolved phenomena of ozone depletion, e. g. by means of direct measurements in the stratosphere and greater use of computer programmes. Other funding priorities include *aerosol research* and the *cooperative interdisciplinary programme 'Pollution associated with aviation',* which is designed to determine the ecological impact of growing international air traffic volumes. Between 1993 and 1995, the BMBF provided approximately DM 12 million for these research activities.

An important institution in the field of climate research is the *Deutsches Klimarechenzentrum* (DKRZ – German Climate Computer Centre) in Hamburg, which is primarily funded by the BMBF (see box).

The climate research workshop

The Deutsches Klimarechenzentrum (DKRZ – German Climate Computer Centre) in Hamburg uses global coupled ocean-atmosphere models in order to estimate future climate trends and the human impact on the climate. The model calculations carried out in Hamburg (which took into consideration increasing greenhouse gas concentrations and the impact of sulphate aerosols) showed that the temperature has increased by 0.3 ± 0.1 °C in the past 100 years. Data from observations made during the same period of time showed a temperature increase by 0.45 ± 0.15 °C (IPCC 1995). It is highly likely that this increase in temperature is not exclusively due to natural causes.

Environmental protection across national borders

Environmental protection is a global challenge which requires international cooperation. In view of this fact, the BMBF participates in a large number of international activities.

Organising environmental protection at supranational level

An exemplary case in point is the EUROENVIRON project carried out in the framework of the European EUREKA research initiative. The purpose of this project – in which 18 countries and the European Commission are now participating – is to coordinate international innovative research and development projects in the environmental sector.

The Federal Government also provides funding for projects carried out in other parts of the world. *Tropical forest research* is focused on the Amazon region and the tropical littoral forests in Brazil. The research activities funded by the BMBF include, for instance, 'Studies on Human Impact on Forests and Flood Plains in the Tropics' (SHIFT) in Brazil. Under a programme entitled 'Support of application-oriented tropical forest research', the Federal Ministry for Economic Cooperation (BMZ) provides funding for scientific silvicultural studies designed to support the management of natural forests and afforestation measures.

In the field of *climate research,* the BMBF is a member of the International Group of Funding Agencies for Global Change Research (IGFA), which is an association of national institutions from 25 countries. The IGFA is currently preparing a comprehensive survey of global climate research funding activities. A German-Brazilian pilot project in the field of *climate impact research* deals with the availability of water in the north-eastern region of Brazil.

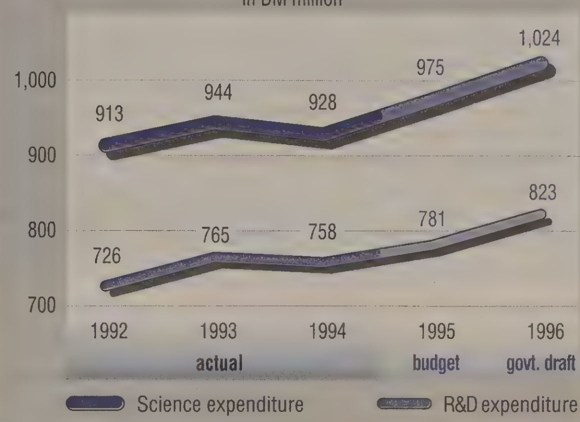
7. Research and development in the service of health (Funding area G)

Funding health research for medical progress

Health research funding is cross-departmental task which involves both research and health policy. *'Health Research 2000'* is therefore a programme which is funded jointly by the BMBF and the Federal Ministry of Health (BMG). The purpose of this programme is to fulfil health and research policy functions, where – according to the German constitution – these fall within the field of responsibility of the Federal Government.

The purpose of the 'Health Research 2000' programme – whose motto is 'Promoting health – Combating disease' – is to help provide an efficient, affordable health system, improve preventive health care, identify causes of diseases, and study new treatment options. In addition, the programme is designed to continue to improve the general setting for health research and to create research structures which will help solve scientific problems quickly and efficiently. The programme's objectives will be attained by funding projects which run over a limited period of time and also by means of research institutions which receive basic funding from the Federal Government.

Federal science and R&D expenditure on research and development in the service of health
in DM million



Source: BMBF BuFo '96

BMBF funding priorities

The BMBF's funding is targeted at four major sectors: biomedical research, public health/health system research, clinical research (see box), and medical technology. Activities in the sector of medical technology are coordinated under the health research programme, while management and funding are part of the following programmes: laser research, microsystems, materials research, and biotechnology.

Creating the conditions for gene therapy

The scope of activities in the sector of biomedical research for disease control has been extended to include new priorities. 'Somatic gene therapy', for instance, is aimed at developing new therapeutic approaches, using molecular genetic methods to treat conditions such as cardiovascular disease and cancer. Other priorities were established in the fields of 'clinical pharmacology' as well as 'neurotraumatology and neuropsychological rehabilitation'. In addition, existing funding priorities are maintained, e. g. in the fields of 'Parkinson's disease and other diseases of the basal ganglia' as well as 'rheumatology research'.

New funding priorities which have been added to the preventive health care and health protection programmes include in particular 'allergology and pneumology' as well as 'addiction research' (see box). Other priorities – i. e. 'fertility disorders', 'public health' and 'health reporting' – were maintained, as planned.

There was also a shift in emphasis in the interdisciplinary priorities of the health research programme; these priorities comprise two objectives: to promote biomedical/clinical research and to improve the structure of research. A case in point is the funding provided for *'interdisciplinary clinical research centres at university hospitals':* Model centres for interdisciplinary clinical research are being built up at eight universities; the start-up funding for these centres is provided by the Federal Government.

Restructuring medical research at universities in the Eastern part of Germany

Other priorities were developed further. In order to support the process of structural change in medical research at universities in the new Länder, the BMBF provides funding in Berlin, Greifswald, Rostock, Jena, Halle, Leipzig, Magdeburg, Dresden and Erfurt, specifically earmarked for the development of research priorities which require cooperation among clinicians and scientists involved in basic research. Now in its second phase, there has been a shift in emphasis: Supplementary funding is provided to help develop new clinical research structures at the institutions which have been selected. Once the priority research areas have been built up, their finan-

BMBF clinical research funding programmes

Based on recommendations made by the Science Council, a number of funding activities in the framework of the 'Health Research 2000' programme are aimed directly at improving the structure of clinical research:

- Between 1988 and 2002, the German Research Foundation will receive approximately DM 216 million from BMBF funds for the establishment of 35 groups of clinical researchers at university hospitals. The purpose of this funding approach is to create small units which are devoted exclusively to doing research and which are closely integrated in the structure of the hospitals. The Federal Government provides the start-up funds, usually for two periods of three years each.
- Start-up funding is provided for interdisciplinary clinical research centres at eight universities selected in a competitive process. The primary functions of these model centres are to promote interdisciplinary cooperation, to develop research profiles for specific universities, to improve the promotion of junior scientists, to achieve demonstrably high research quality, and to establish research funding which is decoupled from medical care.
- The BMBF wants to make it easier for interested non-university institutions which are active in basic biomedical research to build up clinical research activities by cooperating with university hospitals. To this end, the BMBF provides start-up funding to improve the conditions for interdisciplinary clinical research and to promote the medium-term development of tried and tested methods for the handling and funding of projects carried out jointly by university hospitals and basic research institutions.
- Other funding programmes are focused on specific disciplines. In the field of 'clinical pharmacology', for instance, the BMBF has funded model projects at universities since 1992. The purpose of this programme is to help clinical pharmacology to become an independent scientific discipline.

cial needs are increasingly covered by the funds allocated for research and teaching by the Länder governments.

The BMG's departmental research activities

The BMG provides funding for health research projects and model programmes, e.g. in the fields of health systems research, medical quality assurance, care of cancer patients and chronically ill patients, communicable disease control, and psychiatric care; a new priority is addiction research (see box).

Health systems research

The BMG helps accelerate progress in the field of health insurance systems – also at organisational level – and provides funding for a pilot project on electronic data exchange between the German health funds and medical service providers. Other research projects deal with the organisation and cost development of ambulance services, and new trends in the field of auxiliary devices and equipment.

Medical quality assurance

This field includes activities designed to test, validate and improve medical care. In addition, the BMG also provides funding for so-called quality management activities.

Cancer care

The BMG provides funding to test a wide range of quality assurance measures in cancer treatment, ranging from early detection to follow-up care. The purpose of supplementary field studies is to provide findings on improved tumour management; the psychosocial and rehabilitative aspects of the dangerous disease are analysed in model projects. Grants are also provided for the establishment of a bone marrow donor data base.

Addiction research: new strategies to combat contemporary drugs

The BMBF has established a funding priority entitled 'addiction research' which meets the requirements of the Federal Government's 'National Drug Control Plan'. Basic neurobiological/pharmacological studies are expected to provide new findings, e.g. about relapse prevention. In addition, the BMG provides funding for pilot programmes which support the prevention and treatment of addictions by means of evaluating and application-oriented research projects.

Chronic disease management

Under a pilot programme the BMG has – since 1987 – provided funding for projects aimed at the prevention, diagnosis, treatment and follow-up care of chronic diseases. Research in this field is focused on cardiovascular, metabolic, rheumatic and nervous disorders. Furthermore, the BMG provides funding nation-wide for the establishment of regional rheumatic disease management centres.

AIDS control

The anti-AIDS campaign carried out by the Federal Centre for Health Education is addressed at the public at large and at specific groups. The purpose of this cam-

paign is to contain the further spread of AIDS and to prevent any discrimination against affected persons.

Psychiatry

New management concepts for mentally ill patients are tested under a cooperative pilot project, covering various aspects of life such as home, work and leisure. Between 1992 and 1995, the BMG funded studies in 14 regions – in particular in the new Länder – to test innovative forms of home care.

Preventive consumer health protection

In this field, the BMG provides funding not only for studies on specific issues – such as the management of iodine deficiency – but also for general projects which deal with, for instance, the interdependence between nutrition and the development of tumours.

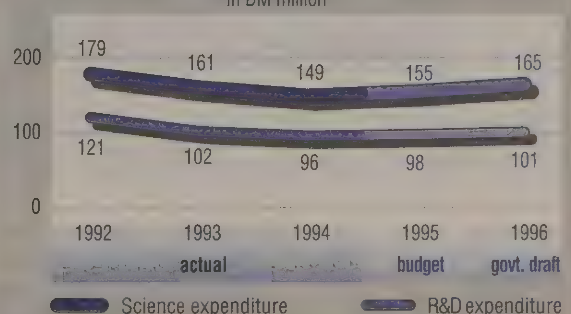
8. Research and development to improve working conditions (Funding area H)

Work 2000: New concepts for factory and office work

The catchword 'lean production' makes it very clear: The organisation of work processes and the design of individual work places play an ever greater role in international competition. Technological innovations alone will not preserve Germany's attractiveness for business enterprises. This means that society is confronted with a dual challenge: using work efficiently, and at the same time, creating a humane working environment by means of modern production and service concepts.

The BMBF and the Federal Ministry of Labour and Social Affairs (BMA) jointly fund an R&D programme entitled *'Work and Technology'*. In the framework of this programme, researchers from various disciplines in cooperation with practitioners develop concepts for modernising the world of work. Since 1993, new forms of work organisation have been developed in the field of factory innovation, which, among other things, integrates production and service processes and promote qualified group work. In the field of office and administrative activities, funding was focused on computer-aided design work. In addition, a research project entitled 'Secretariat of the future' provided fundamental information about employee skill requirements and work organisation if increasing use is made of technology. Other projects which dealt with software – an important competitive factor – provided valuable findings for the future design of the man/machine interface. A cooperative project on specific health risks in waste disposal (which was part of the research efforts on preventive measures in the fields of occupational safety and health protection) attracted attention in Germany and abroad. Other projects carried out in the same field dealt with cancer risk factors and the sick building syndrome.

Federal science and R&D expenditure on research and development to improve working conditions
in DM million



Source: BMBF BuFo '96

Future-oriented issues

In 1993, *medium-term action fields* were developed in the context of the R&D programme 'Work and Technology'. The purpose of these action fields is to concentrate research efforts on major future issues:

– The primary objective is to adopt innovative holistic approaches towards developing modern work, pro-

New priorities

Within the framework of the medium-term action fields, there has been a shift in emphasis towards

- *Services:* The service sector will increasingly be a catalyst for innovation. For this reason, a study entitled 'Service 2000 Plus', which was carried out in the framework of the BMBF's 'Services for the 21st Century' initiative, is designed to identify service opportunities and developmental shortcomings and to develop examples of potential services in future.
- *Demographic change:* The increase in the average age of the workforce coincides with innovation and restructuring processes in the economy. The purpose of analyses and scenarios developed under the R&D programme 'Work and Technology' is to help predict future requirements to be met with regard to the organisation of companies and to employee skills.

duction and service concepts, which will combine a humane work environment with cost-effectiveness.

- In order to prevent health risks from developing at the place of work in the first place, funding is provided in particular to promote preventive approaches.
- New priorities were defined to provide funding for research on urgent issues (see box).

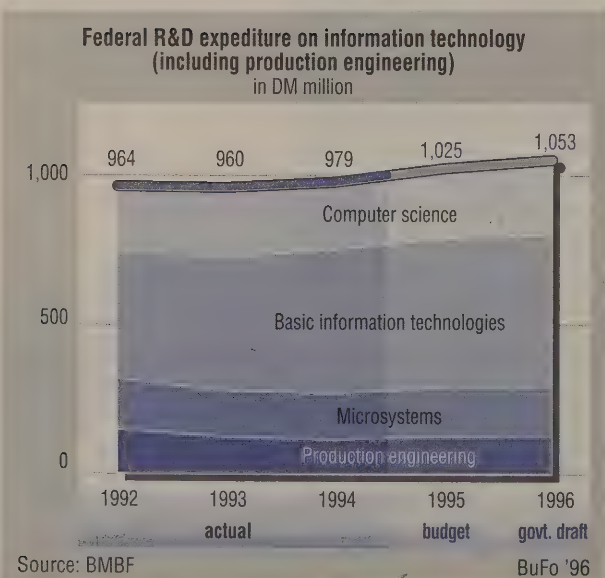
The R&D programme 'Work and Technology' also provides suitable support and impetus for small and medium-sized enterprises as well as for craft establishments. In the new Länder, there are still special funding needs. The experience gained with the programme in the old Länder is applied in the new ones, while taking into consideration the specific conditions prevailing there. When it comes to funding projects, priority is given to projects in the new Länder. The purpose of building up an information network is to gain access to funds for German R&D capacities from European research programmes on occupational safety and technology design.

1995: almost one-third of funds allocated to projects in the new Länder

9. Information technology (including production engineering)
(Funding area I)

Key technologies for the future

The figures speak for themselves: The global turnover achieved by information technology industries (electronics, computer science/software, office systems technology) today amounts to over DM 1,500 billion. In the EU, the industry's turnover already corresponds to 5 % of total GNP – a share which, according to OECD analyses, will rise to up to 10 % by the year 2000. Today two-thirds of all jobs in Europe already depend on information technology, either directly or indirectly.



Because of its strategic importance, information technology is a crucial challenge for the Federal Government's research policy. In order to be fully informed about the various fields of application, problem areas and fields for action in this important sector of innovation, the *Council for Research, Technology and Innovation* to the Federal Chancellor first of all devoted its attention to the topic of *Information Society – opportunities, innovations, challenges,* which it discussed intensively. At the end of 1995, the Council presented recommendations for action, which were addressed to the Federal, Länder and local governments, as well as to industry, to the trade unions and to the scientific community. The information society represents the beginning of a new era. The world will undergo fundamental changes, not only in its technological but also in its economic and cultural structures. Since these structures will become more and more crosslinked, boundaries in terms of time and space will become less important; there will be new symbioses between living at home and working; and the transport of many physical goods in time and space will become superfluous. At the same time, the trend towards globalisation will accelerate. It will be possible to work around the clock at several points in various time zones of the world, thereby achieving productivity gains. There will be new multimedia products

Information society – opportunities, innovations, challenges

which, however, will not replace the current media; instead they will supplement current media and create new room for manoeuvre for the individual. The Federal Government has responded to the challenges associated with these new trends by introducing, among other things, two programmes: the *German Information Society Initiative (IID)* and *Info 2000* (see box).

As early as in 1989, the Federal Government had defined a framework with its programme *Information technology: a concept for the future,* which helped bundle information technology funding, development and application efforts in various policy fields. This research policy framework was filled by the BMBF with its *Information Technology Funding Concept 1993–1996,* which supplemented the basic funding of institutions by appropriating specific funds for projects in the following fields:

- basic IT technologies,
- computer science applications,
- microsystems.

Funds provided in the field of production engineering are designed to improve the competitiveness of German companies.

On our way to the information society

In view of the great opportunities and potential risks associated with the new information and communication technologies, the Federal Government has introduced a broadly-based *German Information Society Initiative(IID)*, involving many sectors of society and a large number of individual citizens. In addition, it published a report entitled *Info 2000 – Germany's transition towards the information society* in February 1996, in which it stated its objectives and presented a comprehensive action plan which it had adopted. This action plan includes views and suggestions made by various groups of the German society, as well as inputs from the European Union and the G7 countries and experience from other countries.

Know-how transfer

Funding of projects carried out jointly by research institutions and companies

Constructive cooperation between higher education and research institutions and business enterprises plays a fundamental role in the promotion of research. This cooperation facilitates the transfer of know-how which is so important for a national economy. For this reason, a large number of the projects funded by the BMBF were – and still are – projects carried out jointly by several partners. This begins with the exploration and dissemination of basic technologies which are needed as a basis for the successful development of products and technologies. In 1996, for instance, the BMBF provided DM 353 million to fund basic technology projects; close to DM 200 million of this amount was used to explore silicon-based microelectronic technologies (see box on basic technologies).

JESSI: Bundling European microelectronics research

In *JESSI* – a EUREKA programme involving the participation of over 3,000 scientists and engineers from 180 companies and research institutions – cooperation extends far beyond national borders. The purpose of this programme, whose main phase of activity is between 1992 and 1996, is to bundle European microelectronics research and to give it strategic orientation. Germany's annual contribution to this programme amounts to DM 200 million, of which 50 % comes from public funds.

The funding of new software developments – a priority of industry-oriented *R&D in the field of computer science* – is provided in close coordination with the software industry and potential users (see box on computer science funding programmes).

Another example of successful cooperation is the *Deutsches Forschungszentrum für Künstliche Intelligenz (DFKI – German Research Center for Artificial Intelligence)* in Kaiserslautern, which was established in 1988 by nine companies, two research institutions and the federal states of Rhineland-Palatinate and the Saarland, based on a suggestion made by the BMBF. After a phase during which the DFKI built up its know-how and staff, the Centre became fully operational in 1994 and has already produced research findings in the fields of knowledge representation, computer linguistics and document analysis – findings which have attracted much international attention.

Basic technologies: progress due to basic research

The most important basic technology involved in information and communication technologies is silicon-based microelectronics.

In the 21st century, information technology will additionally make use of photonic processes there, where electronic processes can come up against the limits of their efficiency. The BMBF has established a separate funding priority for photonic technology with a view to developing a new basic technology by means of suitable materials (e. g. III-V compound semiconductors, polymers) – a technology which will combine the advantages of optics and microelectronics. Electronic and optoelectronic components made of the so-called III-V compound semiconductors such as gallium arsenide and indium phosphide have major advantages compared to silicon components: They switch faster and can not only receive but also transmit light. This makes them the devices of choice for use in superfast computers or cellular telephony systems.

Research networks: global data access

DFN: information highway for research

Research networks which permit global access to data and images have become an indispensable medium for scientists. In Germany, the *Verein zur Förderung eines Deutschen Forschungsnetzes (DFN-Verein – Association for the Promotion of a German Research Network)* has built up a nation-wide network. However, this network has come up against its capacity limits because the number of its users has grown continuously and new applications have been added. For this reason, the BMBF has given the Association start-up funds totalling DM 80 million to upgrade the network speed to access rates of 155 Mbit/s (current speed: 2 Mbit). This will help German research networking to catch up with the top-level standards achieved in other industrialised nations. The DFN Association will play an active role in the educational initiative 'Connecting schools to the Internet'.

Funding priorities in the field of computer science

- Software technology
  Mastering the complexity of integrated software systems, reliable information systems.
- Application of high-performance computing
  Improving the fundamentals of parallel processing and implementing the results in the field of application.
- Intelligent systems
  Developing systems which are able to reason, to learn and to adapt, by means of artificial intelligence (AI), neuroinformatics (NI), and related fields.
- Automatic speech processing
  Developing a portable device which recognises spontaneously spoken words and sentences in a dialog situation, and which translates them into another language.
- Bioinformatics
  Optimising computer science by means of findings from the fields of biology and medicine, while at the same time solving biotechnology problems by means of computer science.

The multimedia challenge

The rapid development in the field of multimedia is also supported by the BMBF. Multimedia is more than just the technical combination of computers and telecommunications. 'Telecooperation', 'telelearning', 'telemedicine', 'teleshopping' or 'teleworking' are only some of the buzzwords which illustrate the host of possible applications by means of which information technology can create enormous economic opportunities and at the same time lead to changes in society. The BMBF supports the dissemination of modern telecooperation technologies in private industry and public administration, as well as the use of multimedia technology in the educational sector. The purpose of promoting modern teleservices is to strengthen Germany's ability to compete with other countries in attracting business enterprises.

Microsystems: market of the future

Since the early 1990s, Germany has been one of the leading countries in the field of microsystems (see box) due to – not least – the BMBF's funding. According to estimates by experts, the market is expected to reach a volume of DM 40 billion by the year 2000. Under the *Microsystems Programme 1994–1999* the BMBF's funding activities will be continued with new priorities. By providing basic funding for institutions, the BMBF maintains the research infrastructure; new cooperative projects are designed to develop new technologies. Since 1994 alone, 67 cooperative projects have been initiated, including a total of 360 sub-projects, and involving the participation of many companies and R&D institutions from the new Länder.

In the field of microsystems, components which sense, decide and react are combined with each other to create miniaturized intelligent systems. It was the implementation of these different functions by combining appropriate microtechnologies (e.g. micromechanics, microoptics, microelectronics) and their assemplation on a chip which made certain technological innovations possible in the first place (e.g. antilock systems and airbags in automotive engineering). Other fields of application include medical equipment and environmental technology.

Production engineering: new impetus for competitive production

Between 1993 and 1996, the BMBF spent approximately DM 480 million to fund research projects in the field of production engineering. These projects were focused on manufacturing technologies, new approaches to quality assurance, and a broadly-based technology transfer to small and medium-sized enterprises. In addition, European cooperation in the field of production engineering was strengthened, not least by means of the *Fourth EU Framework Programme on Research,* which will continue until 1998.

Based on the *Production Engineering Programme 1988–1992*, the BMBF's funding policy rests on two pillars in this field:

Quality management for small and medium-sized enterprises

- The *Quality Assurance Programme* (1992–1996), which is primarily designed for small and medium-sized enterprises, has a volume of DM 350 million. The purpose of this programme is to encourage enterprises to introduce integrated quality management systems. One project which was particularly successful in this context was aimed at the implementation of DIN/ISO 9000 et sqq., which met with great interest on the part of companies from many different sectors (790 participating partners).

Production strategies for the 21st century

- The purpose of the *Production 2000 Framework Concept* (1995–1999), which was developed in a dialogue with representatives from industry, science and the trade unions, is to help companies develop and apply innovative strategies. This includes improvements in the ecological sustainability and flexibility of production processes, shorter development and delivery periods, as well as an extensive integration of information and communication technologies into the in-plant flow of operations. A total of DM 450 million has been earmarked for this framework concept.

Research funding: on our way to the next millennium

In the mega-market of information, standing still is tantamount to going backwards. For this reason, the BMBF is developing a strategic framework concept entitled *Innovations for the information society 1997–2001*. This concept focuses on the following core areas:

- Information technologies for the educational sector,
- upgrading the technology base,
- systems technologies and microsystems,
- innovations in the products sector,
- innovations in the services sector,
- biology and information technology, as well as
- non-technological conditions for innovations for the information society.

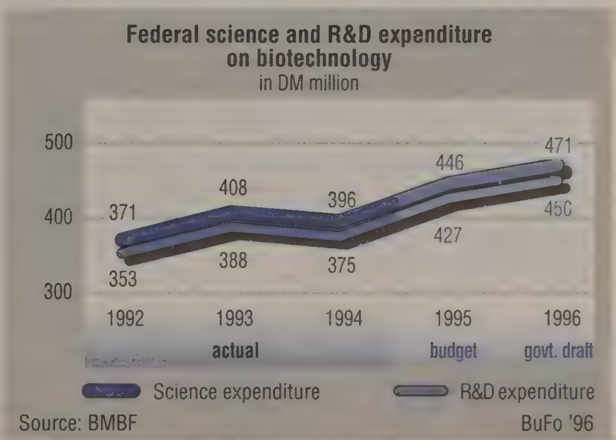
The information society: a vision

This shows that also in the next few years research funding in Germany will continue to focus on the vision of the information society in the 21st century.

10. Biotechnology (Funding area K)

Biotechnology set for expansion

According to the 'DELPHI Study on Technological Development', biotechnology will be involved in half of the 30 most important innovations implemented by the year 2020. The OECD expects biotechnology to become the scientific discipline with the greatest economic importance in the next few decades. Many sectors and industries will stand to gain from this development: not only the pharmaceutical and the chemical industry, agriculture and the environmental sector, but also industries and disciplines in which biotechnological innovations have so far been used to a limited extent only. This applies, for instance, to information and energy technologies, or materials research.



The Federal Government has made biotechnology one of its research priorities. With its *Governmental 'Biotechnology 2000' Programme,* the Federal Government provides specific funding for the expansion of the scientific basis, while at the same time helping to spread the practical application of this technology. The primary purpose of the programme is to promote methods and processes which help protect human health and the environment.

The great importance attached to this funding area is substantiated by the following statistics: Each year, the Federal Government spends over DM 1 billion on funding research and development in the field of biotechnology. Of this amount, of which over DM 900 million comes from the BMBF. More than DM 330 million per year is currently allocated to the 'Biotechnology 2000' programme alone. This is supplemented by activities in other funding areas, where biotechnological issues are also involved to some extent (see Sections 7, 19), and by funds from the DFG and MPG budgets. The MPG expends one-third of its funds for biology-oriented institutes.

Biotechnology – a research priority of the Federal Government

In addition, the BML allocates over DM 100 million annually for biotechnological research projects in the field of renewable resources, and projects carried out at nine of the ten federal research institutions in its area of responsibility.

Basic funding of institutions and project funding

The Federal Government's 'Biotechnology 2000' programme is designed to provide not only general funding for the establishment and expansion of scientific institutions and long-term support of their activities, but also for well defined research projects which are limited to shorter periods of time. The institutions which receive funding include the *National Centre for Biotechnological Research (GBF)* in Brunswick, five 'Blue List' institutes in the new Länder, as well as another 'Blue List' institute in Brunswick. The BML funds departmental research institutions which deal with specific sub-sectors of biotechnology. BMBF project funds were used to provide financial support to universities and Max Planck institutes in developing research priorities in the field of molecular biology by establishing 'Gene Centres' in Berlin, Heidelberg, Cologne and Munich.

Gene centres have been established

Project funding activities are equally diverse, as illustrated by the following examples:

- *'Human genome research'* is aimed at exploring the structure and function of human genomes. This will help develop new regimes for the management of severe diseases such as cancer, cardiovascular disorders and Alzheimer's syndrome.
- The *'Environmental biotechnology'* funding concept is primarily aimed at studying degradation pathways of pollutants. One of the purposes of this research is to help increase the currently known rates of degradation. In addition, tests are carried out to examine potential applications of biotechnology in the field of environmental protection.
- *'The use of biotechnology in plant breeding'* is a programme designed to introduce molecular biology methods in plant breeding, in particular in order to establish new regeneration and selection methods and to manipulate key characteristics of plants at molecular level.
- Another research priority is aimed at exploring *'Methods to replace animal experiments'*. Experiments in which animals are exposed to severe stress or which require a large number of animals should be curtailed as much as possible.

Ethical issues are taken into account

Some potential applications of biotechnology – and in particular of human genome research – raise legal, social and ethical questions, which will have to be answered by politicians and scientists. This is why in the past few years various bodies and institutions have intensively dealt with these questions. It was emphasised that developments with eugenic tendencies would be an abuse of human genetics and should therefore be prevented. By now, concrete proposals have been made to solve issues such as medical practice in human genetics or the protection of genome data against third-party access.

Under the Basic Law as amended on 27 October 1994, the Federal Government is now authorised – in the event of conflicting legislation – to introduce rules governing studies on, and artificial changes in, genomes. With its human genome research funding concept, the BMBF will continue to support the discussion of such issues. A new element which has been added to the concept is the provision of funds for interdisciplinary scientific conferences aimed at determining the status of scientific knowledge and any additional need for research.

Competition between regional biotechnology concepts

- The purpose of the *'BioRegio competition'* is to achieve greater commercialisation of biotechnology. In this competition, preferential funding will be provided to those regions which offer the best conditions for transferring biotechnological

knowledge into products and production processes, and for organising and implementing services.

Overcoming national borders

A large number of research challenges cannot be mastered by individual countries on their own. For this reason, the Federal Government attaches great importance to linking its funding programmes with international activities. The Fourth EU Framework Programme on Research (see Part V, Section 1.1) – in which the funds earmarked for biotechnology research were roughly tripled, compared with the previous programme – provides a much wider scope for such international activities.

A good case in point illustrating this form of complementary research funding is the European project on yeast genome research. In this project, which was concluded at the end of 1995, scientists were able for the first time anywhere in the world to identify the structure of the entire genome of a higher-level organism, using yeast as a model. The main focus will now be on understanding the functions of the genes that have been discovered. It is hoped that this will provide important findings which can be used, for instance, for the development of new drugs and therapeutic approaches.

Integration of Eastern European countries – a step towards pan-European R&D cooperation

In the past few years, cooperation with Eastern Europe has become more and more important. The cooperation with various industrialised nations and developing countries has been further developed. At present, for instance, German scientists are studying questions of molecular biotechnology and biosensor technology in cooperation with researchers from Japan. Genetic engineering methods for use in agriculture, environmental biotechnology and biomolecular engineering are currently being developed together with Israel.

Germany – attractive for investments in research and production

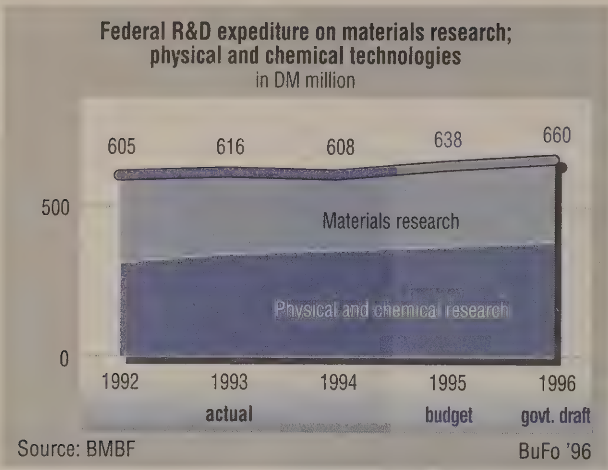
While research has made considerable progress in recent years, the commercial utilisation of modern biotechnology is still in its infancy. For this reason, future funding will have to be more effective than in the past in terms of the development of implementation and market entry strategies. What is primarily needed for this purpose is a suitable legal framework. With the amendment to the Genetic Engineering Act and the amendment to the Genetic Engineering Safety Ordinance, the Federal Government has created the conditions which will allow Germany to continue to hold a leading position internationally with regard to the broadly based commercial utilisation of biotechnology. In fact, the Federal Government wants to continue to increase Germany's attractiveness for investments. To this end, and to implement a decision adopted by the German Bundestag, Parliament's lower house, the Federal Government is trying to obtain an amendment to the EU's directives on genetic engineering.

11. Materials research; physical and chemical technologies (Funding area L)

Materials for the 21st century

Among the technologies which will be ready for the market at the beginning of the 21st century, materials research and new physical and chemical processes will play a key role. Both research sectors receive funding from the BMBF in order systematically to translate promising innovations resulting from basic research into practical applications, which is a necessity if German companies want to continue to succeed in international competition.

In all leading industrialised nations, materials research is perceived as a *key technology*. Germany holds top positions in major sectors of this technology, in particular in the fields of high-tech ceramics, polymers, composite materials, and metal alloys. This is due not least to the successful execution of the *BMBF's 'Materials research programme' (Matfo)*, which ended in 1994 and contributed to creating a diverse and efficient research landscape in Germany.



Interface between basic research and innovative practice

In view of the high importance of materials research, the BMBF decided to continue funding this research sector beyond the turn of the millennium. In June 1994, the BMBF presented a programme entitled *'New materials for key technologies of the 21st century – MaTech'*, which is much more application-oriented than the preceding programme. Consequently, the new programme is focused on the following five major fields of application: information technology, energy technology, transport technology, medical technology, and production engineering. In addition, it also provides funding for cross-disciplinary research on materials and technologies. The total volume of project funds available for this programme, which will extend over a period of ten years, amounts to approximately DM 130 million per year. In addition, a total of about DM 200 million will be made available as basic funding to selected institutes and sub-units of national research centres.

Successful materials research programme to be continued

Modern materials protect the environment

Environmental protection plays an important role in the MaTech programme. New materials are used in particular in *transport and energy technologies* in order to reduce the consumption of resources and the output of pollutants. However, the field of applications covers a broad spectrum, including power plant technology, engine and turbine construction, sensors and actuators, as well as feedback and open-loop control systems.

In addition, with its MaTech programme the BMBF has paved the way for international cooperative materials research. Today, German institutes and companies are cooperating successfully in joint research initiatives with a large number of European and non-European partners. Such cooperative projects have helped to achieve considerable progress, e. g. in the field of high-temperature materials for steam and gas turbines. Furthermore, the programme is complemented at national level by selected, smaller-scale funding activities of several Länder.

Research into *'Physical and chemical technologies'* – is much more oriented towards basic research than programme materials research. At an early development stage this funding priority prepares the ground for future innovations: Findings from basic research are analysed, their technological potential is assessed, and possible industrial applications are sounded out in R&D projects.

Germany's new Länder – integrated into the research landscape

Germany's new Länder play an important role in materials research. The Leipzig-based *Institute of Surface Modification (IOM)*, for instance, holds a leading position in selected fields of surface and coating technologies; it cooperates closely with partners in the old Länder. A large number of research institutions in the regions of Jena and Dresden are concentrating their attention on superconducting technology. The research priority which has developed in Jena is cryoelectronics, involving a large number of application-oriented research topics such as calibrated power sources, SQUID sensors and high-frequency technology. In addition, the BMBF specifically funded studies on high-current superconduction and magnetic levitation technology which were performed in the region of Dresden. The findings obtained from these studies can be applied in particular in electrical energy technology. In the field of plasma research, there have also been several examples of successful integration: e. g. the *Institute for Nonthermal Plasma Physics* at the University of Greifswald.

Making use of potential applications early on

In the past few years, this highly traditional funding area of the BMBF has helped in many cases to mediate between both poles. Major research areas were brought closer to applications. This applies, for instance, to high-temperature superconductivity and surface technologies, as well as modern catalysts such as zeolites. Research fields which have only recently begun to emerge have also been examined with regard to potential applications. Such fields include adaptronics, non-linear systems, nanotechnologies, supramolecular systems, supercritical fluids, and chemical microreactors. The total volume of project funds earmarked by the BMBF for this research priority amounts to DM 130 million per year. These project funds are complemented by basic funding allocated to all major institutions, as well as the MPG and the FhG.

DM 130 million annually allocated to projects in the field of chemical and physical technologies

International cooperation opens new perspectives not only for materials research but also for physical and chemical research. Joint projects are currently pursued with a number of partners from the EU and also with scientists from India, Russia, and Ukraine.

Among physical technologies *laser research and technology* should be specifically emphasised:. With its *'Laser 2000' funding priority* and the preceding *'Laser research and laser technology'* programme, the BMBF has initiated the development of an efficient research landscape for this technology sector in Germany, covering a broad spectrum of disciplines and regions. The results which this publicly funded research has produced to date are already being applied in many areas, e. g. in the fields of environmental monitoring, laser TV, car manufacturing, shipbuilding, and medical equipment. The 'Laser 2000' programme, which will be in effect from 1993 to 1997, is aimed at two major objectives, i. e.

- to develop new laser equipment generations (in particular diode pumped solid-state lasers) with a view to achieving new wavelength ranges, higher yield, and beam quality, and
- to open up new fields of application.

Funding of laser research

Between 1992 and 1995, the total volume of funds provided by the BMBF for laser research and laser technology amounted to approximately DM 244 million. Funding was focused on research in the areas of radiation sources, laser measuring technology, and laser medicine. This work is complemented by research on laser safety and standardisation as well as continuing training.

The international projects carried out in the framework of the *EUREKA Technology Programme* play an eminently important role in the field of laser technology. Approximately 16 % of the funds appropriated for R&D projects in the field of laser research is spent on international projects. At national level, there are strong research capabilities in the *new Länder.* Until the end of 1995, the total volume of funds allocated to roughly 145 projects in the new Länder amounted to approximately DM 79 million.

In the wide-ranging fields of materials development, physics and chemistry, R&D efforts will also be required to prepare standards, measuring and testing procedures, as well as safety guidelines. These activities fall into the area of responsibility of the Federal Ministry of Economics and are executed by the *Federal Institute of Materials Research and Testing (BAM)* and the *Federal Institute of Physics and Metrology (PTB).*

12. Aeronautical research and hypersonic technology (Funding area M)

Boost for German and European aeronautical technology

The aeronautical industry is characterised by rapid technological progress. In fact, this progress determines the competitiveness of the manufacturers. The US industry has increased the competitive pressure on European manufacturers, also with the help of billions of R&D funds from the public budget. For this reason, the Federal Government established a programme for the period from 1995 to 1998 to provide funding for civil aeronautical research and technology.

The primary objectives of the programme, which is funded jointly by the BMBF and the Federal Ministry of Economics, are to develop technologies for new passenger aircraft for long distances as well as for short and medium distances; to improve helicopter technologies; and to design environmentally sound propulsion systems. A major objective of technological developments of the research programme is to reduce aviation-related environmental pollution (see box).

The civil programme complements the Federal Government's other activities in aeronautical research. These include basic funding provided jointly by the BMBF and the Ministry of Defence to the *German Aerospace Research Establishment (DLR),* as well as the specialised programmes funded by the Federal Ministry of Defence and the Federal Ministry of

Federal R&D expenditure on aeronautical research and hypersonic technology
in DM million

Source: BMBF BuFo '96

Research objective: ecologically sustainable aviation

The national cooperative programme 'Aviation-related pollution' was established in 1993. The purpose of the programme's atmospheric research component is to study the effects of global aviation on ozone distribution and the climate. These studies, which are closely linked to European and NASA research projects, provide the general setting for the technology work carried out in the framework of the aeronautical research programme. In this context, the primary objectives of aeronautical research are:

- to reduce CO2 and nitrogen oxide emissions,
- to reduce fuel consumption,
- to reduce aircraft noise.

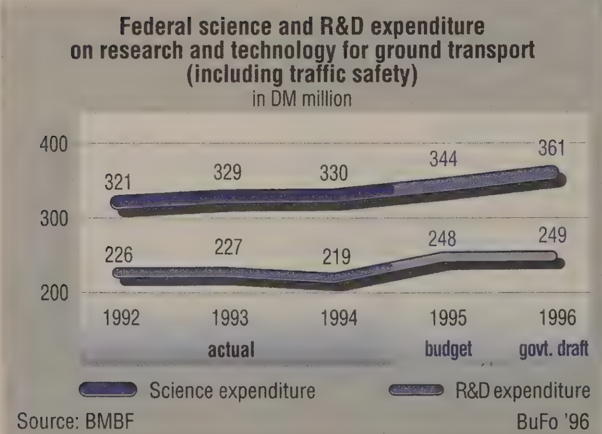
Transport, and the funds provided by the Federal Ministry of Economics to cover development costs; since 1991, these funds have been reduced as scheduled, and in 1996, this scheme in its current form will be discontinued (Airbus programme).

Ecological sustainability – as well as cost-effectiveness – also played a key role in Germany's research on hypersonic technology (concept for a new generation of space transport systems). Since 1988, DASA has cooperated with MAN, the DLR, higher education institutions and foreign partners under a national programme which has produced some fundamental results. For both technical and financial reasons, the German side in the future wants to implement the hypersonic concept in close cooperation with strong European or international partners.

13. Research and technology for ground transport (including traffic safety) (Funding area N)

Mobility and transport – on our way to the future

Speeding from Hamburg to Berlin in an hour's time – in the TRANSRAPID. The technology involved is already so advanced that the Federal Government decided in March 1994 to build a magnetic levitation line between Germany's two biggest cities. Every ten minutes, a TRANSRAPID train will travel along the 280 km line at a speed of up to 400 km/h. The TRANSRAPID is only *one* example which shows how traffic can be shifted from aviation and road transport to ecologically more preferable modes of transport.



Any government which wants to reduce road and air traffic volumes, will have to offer attractive alternatives to its citizens and industry alike because both in professional and in private life there is a growing need for mobility. Transport and traffic will play an increasingly important role in future, particularly in Germany, which is a central transit country in a now integrated Europe and which is also a neighbour to Eastern Europe. These growing traffic volumes will lead to problems, in particular in the environmental sector. It is up to society to develop innovative and sustainable solutions.

Increasing mobility without polluting the environment

The purpose of research and development in this field is

- to create the scientific and technological conditions for an integrated overall transport system,
- to make more effective use of the existing transport infrastructure and to reduce unnecessary traffic,
- to reduce the environmental impact and the consumption of resources associated with traffic,
- to cope with traffic in conurbations,
- to increase road safety.

TRANSRAPID – environmentally sound and innovative

There are three objectives which the Federal Government is pursuing with the TRANSRAPID train:

- to shift road and air traffic to track-bound transport systems; this will help to improve the performance of the transport sector in terms of energy budget and life-cycle analysis;
- to create free railway capacity for regional transport and goods transport, and to develop free capacity at airports for medium-range and long-distance traffic;
- to stimulate the economy by means of technological innovations.

New key technologies help accelerate public passenger transport

The development of some of the key technologies in the field of high-speed passenger transport has been largely completed. It has been demonstrated that the TRANSRAPID is ready to be used for scheduled service (see box). Another example is the ICE high-speed train: Modern multi-system-capable trains will make 'a Europe without frontiers' a reality in the field of rail transport. Public municipal passenger transport will also have to become more modern and more efficient. A satellite-based positioning system will ensure that traffic lights will always be switched to green in city traffic when buses approach; unmanned underground and light-rail rapid transit systems will permit the flexible use of vehicles, irrespective of rigid duty rosters. In the field of regional transport, use will be made of light-weight railway systems which offer more flexibility and consume less energy than conventional systems.

MOTIV – the integrated traffic guidance system

Based on PROMETHEUS, the MOTIV project (Mobility and Transport in Intermodal Traffic) is being prepared. MOTIV will enable travellers to select the optimum route and the most suitable mode of transport by means of modern information and communication technologies. MOTIV will link public with private transport and also takes into account the need to park vehicles, i. e. the availability of parking facilities at a given location. The purpose of MOTIV is to make more effective use of the existing traffic infrastructure, optimise the use of modes of transport, and reduce environmental pollution.

Reducing environmental pollution caused by road transport and traffic

New approaches will also be adopted in the field of private transport to prevent road traffic congestion and thus reduce environmental pollution. In the field of vehicle design, new safety systems will be devised for small vehicles, electric cars will be tested, and low-emission drives will be developed for lorries.

Modern logistics concepts for goods transport

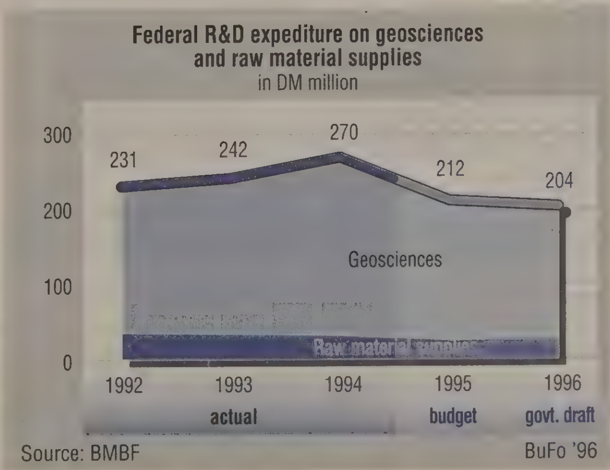
Another research priority is goods transport. The concept of 'combined transport' was developed in order to reduce traffic density on trunk roads. 'Combined traffic' is a modern logistics concept which effectively combines road and rail transport. The BMBF provides funds to support the design of goods transport centres so that more goods can be transported by means of 'combined transport'. These centres will be used to transship and distribute freight – primarily from long-distance rail transport to short-distance modes of transport. In international traffic, the sea ports play the key role within the entire transport chain. Funding was provided to transform sea ports into modern logistic service centres under a research priority programme called 'Innovative sea port technologies' (ISETEC), which has now been completed.

14. Geosciences and raw material supplies (Funding area O)

Research in the lithosphere

The continental crust of the Earth is humanity's habitat and most important source of raw materials. However, the Earth's crust also poses direct threats to its inhabitants in the form of earthquakes and volcanic eruptions. Geosciences help understand, use and protect this habitat. Because of geoscientific research findings, it is possible, for instance, to detect existing raw material deposits or to curb the repercussions of natural disasters.

In the past two decades, completely new findings have been obtained with regard to the structure and the development of the lithosphere. The concept of plate tectonics, for instance, has made it possible to draw new conclusions about the genesis and decline of orogenic belts, and about continental transformations. The studies conducted under the international Deep Sea Drilling Project, which was successfully



completed, played a major role in this context. Research interest is now increasingly focusing on studying the continental crust of the Earth. The activities funded by the BMBF in the context of its *'Geosciences' priority* have made a major contribution to these results:

Knowledge of the lithosphere considerably increased

Over a period of thirty years, the *'German Continental Reflection Seismic Programme (DEKORP)'* was focused on studying the structures of German Variszian organic belt. This research will be continued in future with a new focus as the 'DEKORP 2000' project, which is aimed at providing deep seismic profiling of the continental crust. Another programme which was designed to provide basic findings was the *'Continental Deep Drilling Programme of the Federal Republic of German (KTB))*, whose purpose was to explore the chemical and physical conditions and processes down to a depth of almost 10 kilometres below the Earth's surface – an unprecedented R&D project world-wide.

Disaster research provides active support

The work of seismic and volcanological experts is very pragmatically oriented. In order to be able to take immediate action in response to natural disasters such as earthquakes and volcanic eruptions, an 'Earthquake Task Force' was established at the *Geoscientific Research Center (GFZ)* in Potsdam. There is close interdisciplinary cooperation among geoscientists, as well as engineers and sociologists. In addition, the scientists working at this centre are drawing up a seismic hazard map for Central Europe. Furthermore, the *Federal Institute for Geosciences and Raw Materials (BGR)* which reports to the Federal Ministry of Economics operates a seismic observation centre in Gräfenberg.

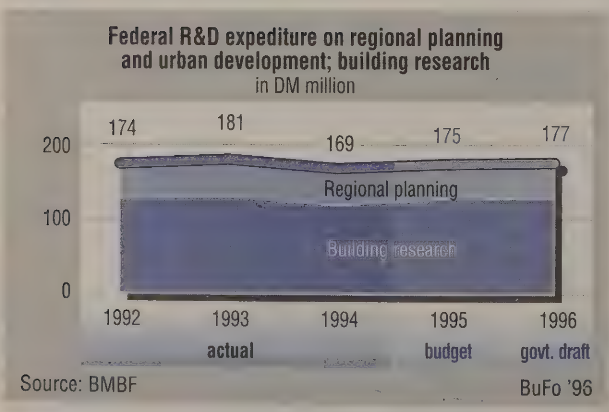
Guaranteeing long-term raw material supply

As an industrialised nation, Germany depends on the supply of raw materials. The BGR prepares a wide range of reports on the national and international raw material supply conditions; these reports are used as a basis providing policy-makers, scientists and the business community with the necessary information.

15. Regional planning and urban development; building research
(Funding area P)

Improving housing and living conditions, modernising and maintaining infrastructure

Germany's unification created new challenges for the country's regional planning and building policies: Today, the legal mandate to create comparable living conditions in all of Germany is more an issue then ever before. At the same time, European integration changes the requirements to be met by regional planning, the transport network and technical building standards. Departmental research funded by the Federal Ministry for Regional Planning, Building and Urban Development and the Federal Ministry of Transport provides the basis for improving housing and living conditions and for modernising and maintaining the infrastructure in the building and transport sectors.



There are numerous projects funded by the Federal Ministry for Regional Planning, Building and Urban Development (BMBau) which are designed to develop the scientific foundations for its departmental policies. Research carried out to support *regional planning policy* is focused on reducing regional imbalances between the old and new Länder, and on preserving a decentralised and sustainable regional and settlement structure. The first result of this research has been a regional planning framework for action, which is aimed at strengthening the decentralised regional and settlement structure and reducing the burden on regions with high traffic density. Studies conducted in the ambit of *urban development policy* are guided by the model of sustainable urban development, with special consideration being given to the development of cities in the new Länder. In the field of

Framework concept defines models for future regional development

housing policy, research is focused on the effects of tenancy law and the reform of legislation related to publicly funded housing construction. Finally, the projects which are designed to support *building policy* primarily deal with the implementation and the effects of the EU Building Products Directive.

In addition, pilot projects carried out within the framework of *experimental housing construction and urban development* provide practically oriented findings, for instance, about mixed-use approaches and reduced pollution in urban development. The purpose of *technical building research,* on the other hand, is to develop measures aimed at reducing costs and avoiding building damage in the field of housing construction. Other issues studied in this context include ecological building practices; in addition, research in this field is expected to provide decision-making support with regard to building provisions in the context of civil defence and disaster control.

Preserving architectural treasures

Architectural monuments are part of our cultural heritage which should be preserved for future generations. For this reason, the BMBF has provided funding since 1986 for extensive research efforts aimed at preserving historical monuments. To this end, an interdisciplinary group composed of scientific institutes and curators of monuments was established, in particular to study natural stone structures, historical brick masonry and half-timbered walls. New diagnostic and treatment methods have been developed to stop the increasing decay of historical buildings. The new findings are currently being demonstrated in approximately 40 pilot structures, primarily in the new Länder; until 1998, these findings will increasingly be put into practice.

The *Road Construction Research* priorities of the Federal Ministry of Transport (BMV) are guided by the ministry's current transport policy objectives. The projects are aimed at studying questions relating to road construction and transport technology, with particular consideration being given to ecological concerns in the planning, construction and operation of roads. The harmonisation of technical rules within the EU is particularly important at present. Research on waterway construction for navigation mainly deals with the technical principles and rules which are necessary for the maintenance and modernisation of federal waterways. This research is primarily carried out by the *Federal Institute for Waterway Engineering (BAW),* which reports to the Federal Ministry of Transport.

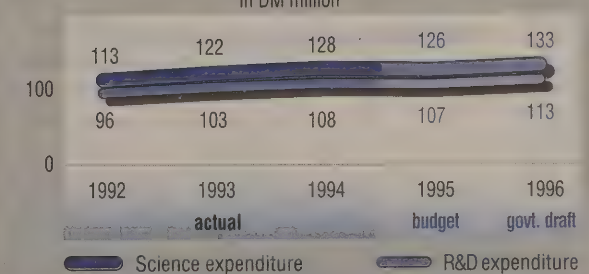
16. Research and development in the food sector
(Funding area Q)

Health-conscious eating and drinking – research helps make the choice

When it comes to their own nutrition, consumers are becoming more and more critical. They expect their food products to be safe for consumption, free of any defects, as well as highly nutritional and as natural as possible.

Issues such as these are the subject of research priorities in the food sector. The research institutions involved, for instance, are developing standardised methods for determining ingredients, and they assess food products – in particular genetically engineered products – from a nutritional perspective. Furthermore, they are developing microbiological methods designed to apply 'soft' processes in food production. These research findings are not only useful for improving existing food products and developing new ones and for implementing governmental food control, but they also help consumers who want to make buying decisions based on facts. Nutritional research is one of the sources of the well-founded information required for this purpose.

Federal science and R&D expenditure on research and development in the food sector
in DM million

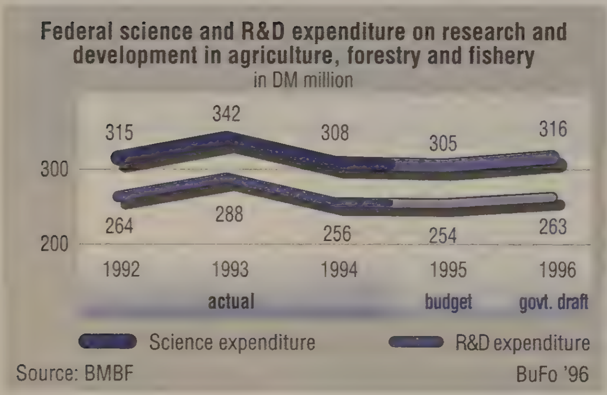


Source: BMBF
BuFo '96

17. Research and development in agriculture, forestry and fishery
(Funding area R)

Healthy plants and animals

In 1995, German agricultural research made considerable progress in the field of biotechnology: At several locations, biotechnologically modified forms of various agricultural crop plants were tested outdoors.



In cooperation with industry, universities and federal research institutions, it was possible to remove the resistance to conducting field experiments with biotechnologically modified plants. This has given an opportunity to German researchers in general – and crop plant breeding researchers in particular – to catch up with foreign competitors, and it has made it possible to make use of the potential of modern biotechnology in the agricultural sector as well.

The overriding concern in agricultural research is to optimise agricultural production so as to increase its efficiency and competitiveness and to achieve compliance with the ecological principles of sustainability.

Biotechnological methods help improve plant protection

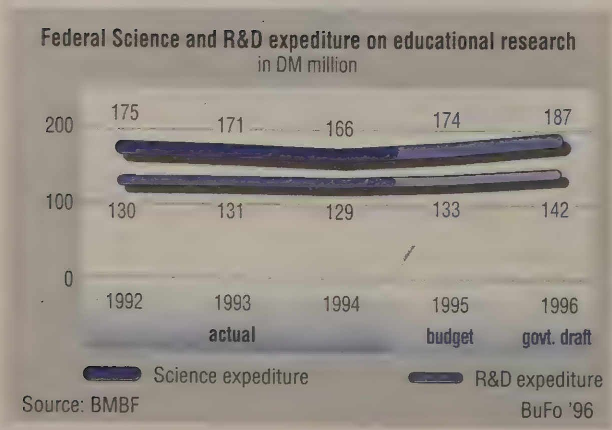
The purpose of research on plant production is to create 'healthy plants' which will be more resistant to pests and diseases, e. g. owing to the application of biotechnological methods. In addition, research efforts are also aimed at studying the industrial use of biogenic products as renewable resources. First successful applications include the use of vegetable oils for total-loss lubrication.

In addition, the Federal Government has increased its funding of institutions and projects whose purpose it is to analyse the ecological impact of agriculture. Research is also carried out to identify potential effects of negative environmental factors (e. g. climate change) on agricultural production, and to develop agricultural countermeasures.

18. Educational research (Funding area S)

Prerequisites for a future-oriented educational policy

The world of work as a whole, as well as many specific occupations, are subject to a continuous and increasingly rapid process of change. The educational system has to stay abreast of this development; to this end, educational policy requires well-founded decision-making support. With its funding of research in the fields of education and vocational training, the Federal Government is helping to develop tomorrow's skill standards in time.



An individual's prospects in life are determined by the education which that person receives. It is the Government's responsibility to adapt general educational opportunities to the constantly changing living and working conditions of the population. The BMBF's departmental research plays a fundamental role in this context. This research relies on a large number of external *educational research institutions* which receive either basic funding or funds for specific projects they are awarded. Above and beyond its

departmental research, the BMBF is also involved in scientifically supported *pilot projects* which – pursuant to Art. 91 b of the Basic Law – cover all sectors of education: nursery schools, primary and secondary schools, vocational training in the 'dual system', higher education and continuing education. One priority in this context is the execution of studies and development projects aimed at improving educational and professional opportunities for women and girls; at present, about 10 % of all projects which are carried out in the fields of primary and secondary schools, vocational training, higher education and continuing education are devoted to this issue.

Integrating labour market requirements in education and training

Research in the field of higher education will continue to be focused on increasing study efficiency. One of the objectives is to reduce the gap between academic training and professional practice while at the same time reducing the total length of academic studies. In addition, tests are carried out in order to examine whether the use of *new media* can help students to conclude their studies earlier. In certain specialised fields of study, *environmental subjects* will become an integral part of the curricula. In addition, it will be important – in the interest of 'life-long learning' – to use *continuing scientific education* more effectively than in the past to build a bridge between university studies and professional practice.

Vocational training research continues to play a particularly important role in the *provision of a sufficient range of training opportunities.* One of the research projects funded by the BMBF in this field aims to identify conditions which either promote or hamper the willingness and ability of companies to train apprentices. Furthermore, regular surveys are carried out among companies in order to detect *new skill requirements* as soon as possible, so as to be able to respond to changes in the labour market quickly by providing new training courses. In the context of a special action concept, the BMBF provides funding for the development of measures designed to support *young people with learning difficulties* who – more than any other group – must be given opportunities to acquire vocational skills. As far as particularly *talented trainees* are concerned a comprehensive study will be conducted to identify the demand for, and supply of, attractive additional skills.

Schools, vocational training, higher and continuing education

In these sectors, the BMBF funds research projects which are of fundamental importance for all educational sectors:

- Organisational and institutional developments:
  - more responsibility (greater independence of educational institutions),
  - quality assurance in the educational sector (increasing performance by evaluation),
  - upgrading the skills of staff (support and further education systems),
  - opening up educational institutions (closer cooperation),
- new information and communications technologies,
- inclusion of environmental issues,
- fine arts and cultural education,
- girls and women in the educational sector
- differentiated support for specific groups.

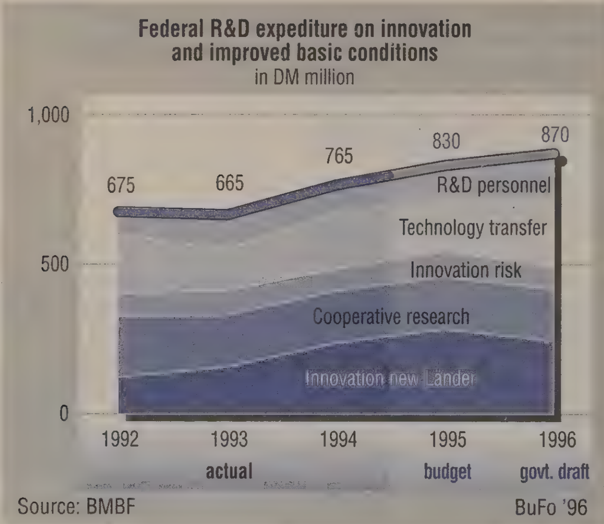
In addition to funding these research sectors which are especially focused on higher education and vocational training, the BMBF also finances studies on a number of more generic subjects (see box).

19. Innovation and improved basic conditions (Funding area T)

Research for small and medium-sized enterprises

Innovation has nothing to do with the size of a company: Small and medium-sized companies also have to stay abreast of technological progress in order to be able to succeed in international competition. For this reason, R&D funding is not limited to large-scale projects or specific fields of technology. Instead, so-called indirect funding is used to support the general innovation process in small and medium-sized firms in trade and industry. In this context, the Federal Government attaches particular importance to companies which are based in the new Länder.

The old, established mechanical engineering firm with 50 or 100 employees, the young electrical engineering firm, or the up-and-coming computer specialist which



markets its software products world-wide: Today, all of these enterprises are obliged to optimise their products and production processes continuously. However, it is often difficult for small and medium-sized enterprises (SMEs) to gain access to the latest technological know-how; in addition, the R&D expenditure by smaller companies is high compared with larger companies.

The BMBF's funding of research activities in the sector of 'Innovation and improved basic conditions' is designed to deal with the specific problems encountered by this group of companies. These research activities are not focused on specific technologies; instead, they help to create the basic conditions for the rapid development, dissemination and application of leading-edge technologies. In addition, the various research activities are generally oriented towards the highly diverse innovation needs of this very heterogeneous target group.

Selective, yet flexible

Since funding is linked to the general innovation scene, the projects funded cover a wide variety of fields without being confined by any specific requirements in terms of the R&D subject. In addition, the BMBF uses a wide range of different financial aids such as non-repayable grants or low-interest loans. The activities to be funded are designed in such a way that funding can be applied for and used with very little administrative effort involved.

Stabilisation of industrial R&D in the new Länder

A large portion of the funding programme is tailored specifically to suit the needs of the new Länder, and rightly so, because the profound economic restructuring process in the Eastern part of Germany was accompanied by a considerable decline in industrial R&D (see box). Owing to the funding programme, industrial research has stabilised in the new Länder. Nevertheless, the scope of R&D in the business enterprise sector is still rather limited. For this reason, the Federal Government will continue to support the development of the research system in the new Länder; the contribution of the new Länder to the overall funding volume will increase more and more. In order to supplement the public funding programme, the Federal Government expects industry to make efforts of its own such as awarding research contracts to independent R&D institutions in the Eastern part of Germany, and shifting research capacity to the East.

Overview: R&D support for small and medium-sized enterprises in the new Länder

- Within the framework of the scheme for *funding of additional R&D personnel* the BMBF provided grants towards payroll costs to companies if they recruited additional scientists and engineers.
- A BMWi programme – *R&D personnel funding in the new Länder* – was addressed to SMEs which employ R&D staff.
- *Contract Research and Development East* was a BMBF funding programme which enabled small and medium-sized companies to obtain grants if they awarded R&D contracts to external institutions.
- In the framework of its *Contract Research and Development West-East* programme, the BMBF provides grants to R&D institutions to help them cover their contract costs.
- Funding provided by the Federal Ministry of Economics (BMWi) to technology transfer centres in continuing education institutions of trade and crafts.
- One of the BMWi's *projects for improving technology transfer* is designed to fund the development of 21 Agencies for Technology Transfer and Innovation Support and 13 additional industry-specific and technology-specific transfer centres in the new Länder.
- The BMBF's pilot project for *New technology-based firms* provided support for newly established firms. A second pilot project helped *to build up and develop technology centres.*
- With its *product renewal programme*, the BMBF provided funding for key technology sectors.
- The BMWi's *pre-competitive industrial research* scheme provides funding to support the establishment of private research companies (Forschungs-GmbH) and private operations hived off from institutes of the former Academy of Sciences.
- With its *development of new products and processes programme*, the BMWi helped reduce the above-average innovation risk for companies based in the new Länder.

Cooperative development as well as know-how and technology transfer

Achieving leading-edge research results alone is not sufficient for a company to prevail over its competitors in other countries. A company which wants to be competitive also has to be able to translate the findings obtained through research into a competitive edge in the market. For this reason, companies and research institutions have to cooperate as closely as possible. However, it is equally

important that companies cooperate with each other in the development of new processes or products. To this end, the Federal Government has been providing systematic support for the acquisition and transfer of know-how and technology, for instance, through the following funding programmes of the BMBF:

- *'Supporting research cooperation among small and medium-sized enterprises':* Until the end of 1995, the total volume of funds appropriated for 2,016 projects amounted to DM 246 million, of which 30 % went to companies in the new Länder.

- *'Contract Research and Development East' (AFO):* Until the end of 1995, a total amount of DM 145.5 million was spent to fund 2,255 contracts of 1,375 companies. The total volume of the contracts supported amounted to over DM 425 million, of which 78 % went to contractors based in the new Länder.

- *'Contract research and development West-East' (AWO):* Until the end of 1995, a total of DM 175.3 million was spent to support 2,235 contracts awarded to 774 research institutions. The total volume of contracts funded amounted to approximately DM 460 million. About 90 % of the R&D contractors who received funds were privatised R&D institutions and companies. Thus, AWO plays an important role in preserving and strengthening research capacities in the new Länder.

Industrial research associations

The BMWi has provided funding for innovative cooperative projects and know-how transfer since 1954. The programme supporting *industrial cooperative research* provides grants for projects which involve several companies. At present, funding is provided to 107 research associations involving primarily SMEs which also spend funds of their own to develop innovations for their companies. In the entire period during which the programme has been in effect, the total volume of funds spent to support over 10,000 projects amounted to approximately DM 2.6 billion, of which over DM 900 million was made available between 1991 and 1995. About 28 % of this amount was transferred to research institutions in the new Länder. The purpose of *projects for the improvement of technology transfer* – a programme which was established in 1989 – is to disseminate new findings among SMEs in the interest of promoting their practical application. The funds appropriated under this programme are not given directly to specific companies but to so-called 'technology agencies'. In Germany's new Länder, for instance, funding was provided to support the establishment of 21 'Agencies for Technology Transfer and Innovation Support' with nine branch offices, and an additional 13 transfer centres devoted to specific industries or technologies. Between 1991 and 1994, a total of approximately DM 120 million was spent on technology transfer. The total sum available for 1995 amounted to DM 40 million.

Strengthening equity capital

Many new and small companies are confronted with a very specific problem: In the years up to their market entry, they do not have the necessary funds to finance high development expenditure. Hence, they depend on equity investments to implement expensive and high-risk innovation projects. The Federal Government has also responded to these needs by means of the following programmes:

- *'Direct-investment capital for young technology-based companies' (BJTU)* is a pilot project which created incentives for making equity investments in such companies. Between August 1989 and early 1995, a total of approximately DM 314 million was mobilised for 336 companies.

- *'Direct-investment capital for small technology-based companies' (BTU)* is a follow-up programme which provides two services: refinancing by means of the *Kreditanstalt für Wiederaufbau* (KfW – Reconstruction Loan Corporation), as well as co-investments by the *Deutsche Ausgleichsbank* (German Equalisation Bank). The total equity investment volume envisaged amounts to DM 900 million; in 1995, over DM 120 million was mobilised.

- In Germany's new Länder, these support programmes are complemented by a pilot project for *'New technology-based firms' (NTBFs)* which offers not only funding but also consultancy services. Until the end of 1995, the project had helped establish 280 new companies. The total funding volume amounted to DM 195.7 million.

In the framework of the NTBF programme, the Federal Government provided an additional DM 41.4 million to support the establishment of 15 technology parks and business incubators in the new Länder. To date, approximately 700 technology companies – most of them recently established – have benefited from low rents and synergistic effects such as the joint use of office and administrative facilities. Approximately 4,000 skilled jobs have been created by these companies.

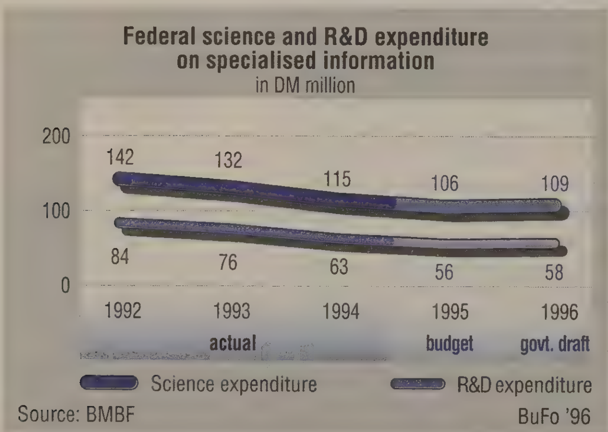
20. Specialised information (Funding area U)

Searching for information in the data network

Successful performance by German providers of scientific and technological information: In 1994, they achieved a turnover of $ 73.3 million, which was 60 % more than in the previous year. The 10 % annual growth rate observed in the Federal Republic of Germany is clearly higher than average world market growth (8 %).

Electronic transfer of know-how directly to the workplace

The Federal Government successfully supported this development with its *Specialised information programme 1990–1994.* In coordination with other participating ministries, the BMBF is currently developing a new concept which will be aimed at a clearly defined objective: In future, scientists and other users will be able to access all electronically available information *from their workplaces* in a cost-effective and efficient manner. At the same time, the new programme is designed to strengthen the scientific and commercial self-government of specialised information centres.



It will only be possible to attain this objective if all the parties involved cooperate closely. State aids will continue to be necessary for this purpose. After all, specialised information centres accounted for two-thirds of the industry's total turnover in 1994. Numerous successful projects are evidence of the fact that the cooperation between public and private funding organisations can produce positive results for all the parties concerned. Small and medium-sized enterprises, for instance, can make more effective use of patent information because of a project entitled *'Stimulating innovations in German industry by providing scientific and technical information'* (INSTI), which the BMBF has funded since April 1995. Private providers and public institutions cooperate closely in this project, and thus help to create a positive climate for inventors in Germany.

No fear of data bases

Another example of the large number of successful cases of cooperation is a *'Pilot project supporting access to data bases by small and medium-sized enterprises including craft establishments'* – whose German acronym is MIKUM – which ended in 1994. The project was executed by the *Institute of the German Economy* and funded by the BMBF. A total of over 2,500 firms from the manufacturing sector made use of the possibility to obtain information from data bases with the help of external or internal agents.

Making more effective use of specialised information: Pilot projects for scientists

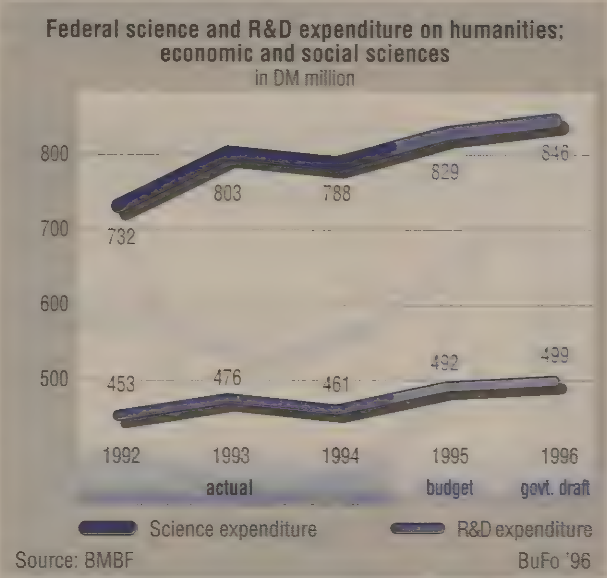
In order to enable scientists to gain access to this medium, the BMBF funded pilot projects carried out by the *German Physical Society* and the *German Mathematical Society;* under these projects, physicists and mathematicians were given an opportunity to familiarise themselves with data bases.

In 1994, a similar project was initiated for chemists in cooperation with the *German chemical Society.* It is the aim of the BMBF to enable other disciplines as well to make greater use of data bases in the future.

21. Humanities; economic and social sciences
(Funding area V)

The *humanities*, as well as economic and social sciences, are very important for the understanding of the structures and foundations of modern industrialised societies. Supporting these disciplines is an important part of the Government's activities aimed at securing Germany's continued attractiveness as an industrial location.

The *humanities* – which along with art and writing are a society's most sophisticated long-term memory – primarily deal with basic research. Nevertheless, the humanities provide many practical opportunities to mediate and establish links in interhuman relations; this applies not only to individuals but also to world cultures. The humanities can help promote national cohesion as well as international understanding. For this reason, funding of the humanities will be more focused in future on the role which the humanities play in society.



Public funding is provided to all disciplines within the humanities. In accordance with Germany's federal structure, both the Federal Government and the Länder governments are responsible for providing funds – in some cases separately, in other cases jointly. In addition to universities – where the humanities are traditionally taught – non-university institutions have recently played an increasingly important role in this field. Recent events along these lines which are within the BMBF's area of responsibility include the establishment of the German Historical Institute in Warsaw in 1993 and of the Geisteswissenschaftliche Zentren (Humanistic Centres) (1992/1995).

Humanistic and sociological research – focused on basic research and problem-solving

Social sciences supply the material (data and indicators) on societal development and work towards solutions for fundamental issues in society. Influencing the scientific and technical, economic and political development of an industrialised society and analysing the most important trends in society – such as the unprecedented *demographic changes* – requires cross-linked inputs from all the various disciplines in the field of social sciences, including law and economics. In this context, socio-economic research is primarily focused on identifying conditions for the stability of societies when under the stress of global impacts on employment and the environment ('sustainable development').

In addition to the research carried out at institutions of higher education, the Federal and Länder governments also provide funding – either jointly or separately – for non-university research institutions and for projects in the fields of empirical social research, technology, science and transformation research, as well as for departmental research carried out by the federal ministries in a variety of fields. The purpose of this departmental research is to provide clues for developing a future-oriented social policy for families, senior citizens, women and youth, and for fighting crime as well as labour market and economic policies.

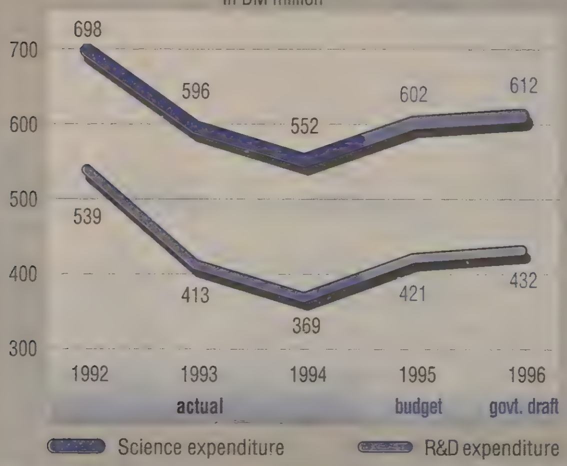
In order to enlarge social science capacities the BMBF is pursuing the following project lines:

- Research on *interactions between technology and society:* The 'Verbund sozialwissenschaftlicher Technikforschung' (acooperative effort of institutions and researchers) is aimed at exploring the organisation of technological innovation processes.
- Development of *science-based social reporting system:* For this purpose the BMBF is compiling all the social data which are collected by instruments funded by the BMBF – in particular data from research on social indicators, transformation research and the optimisation of the scientific infrastructure for empirical social research.
- Inclusion of *Central and Eastern European social sciences:* This objective is pursued not only by EU programmes and network projects in the field of science research. but also by means of the activities carried out by the Institute for Advanced Study in Berlin and a special branch of GESIS.

22. Other activities not assigned to other sectors
(Funding area W)

Research and technology have a major impact on the competitiveness of countries across the world. The Federal Republic of Germany – a country without major natural resources – is particularly dependent on the development and application of efficient technologies. In order to protect the environment – given this background – environmental technology has to be upgraded, and the environmental impact of new technologies has to be taken into consideration during the development phase of these technologies.

Federal science and R&D expenditure on other activities not assigned to other sectors
in DM million



Source: BMBF
BuFo '96

This funding area comprises funding activities of the Federal Government in the fields of science and research which are not assigned to any of the funding areas outlined above.

This includes the field of *Technology Assessment (TA)* to which the Federal Government attaches great political importance. The key interests which are currently being pursued by the Federal Government in this field are to identify the opportunities and risks involved in new technologies, to help eliminate unfounded technophobia by the public at large and actively to create a technology-friendly atmosphere in Germany. In this context, the Federal Government provides funding, for instance, for studies on 'Opportunities and risks involved in genetic engineering from the perspective of the public'.

In the past few years, the BMBF has made major contributions to the development of a highly diverse TA research landscape. One of the priorities has been the development of a TA network in Germany as well as a TA infrastructure in the new Länder, where TA had previously not been established.

In future, the analyses performed in TA research will have to be even more comprehensive in order to make more effective use of the potential desirable effects of new technologies and control the undesirable effects.

Development policy research designed to shape 'One World'

Development policy research is funded by the Federal Ministry for Economic Cooperation in compliance with its departmental functions. Cooperation with developing countries is now being recognised internationally as an important prerequisite to securing our future. Current issues are demographic trends, promoting women, economic structures and conservation of nature.

The *Hochschul-Informations-System GmbH (HIS* – Higher Education Information System), which is based in Hanover, is funded jointly by the Federal and Länder governments as a service institution for universities and university administrations. The tasks of HIS include:

- to develop methods which will help higher education institutions to streamline their administrations,
- to carry out studies and prepare expert reports as a basis for decision-making,
- to develop basis for the construction of universities.

Within the framework funding *International Cooperation* in the field of science, particular attention has been paid in recent years to cooperation with Central and Eastern European countries and the successor states of the Soviet Union. A particular priority in the field of international cooperation is the *exchange of scientists,* which is supported by separate programmes funded by the BMBF and the Federal Ministry of Foreign Affairs.

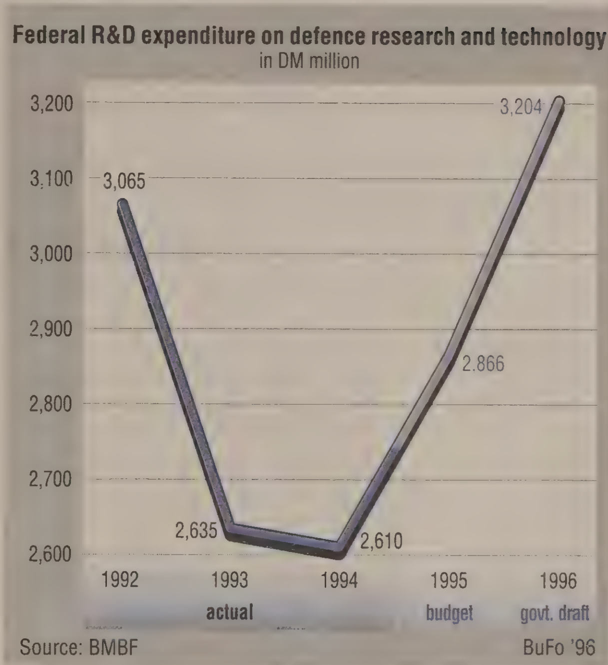
In the field of interdisciplinary *higher education research,* the Federal Government's funding efforts are focused on promoting young scientists and establishing interdisciplinary priorities in the new Länder (innovation-oriented academic research groups).

The BMBF provides basic funding to interdisciplinary *research and service institutions,* including four 'Blue List' institutions, the *Institute for Advanced Study* in Berlin, the German-American Academic Council and HIS (see box).

23. Defence research and technology
(Funding area X)

Preserving Germany's defence and alliance capability

If Germany's Federal Armed Forces are to perform their mission credibly and play their role in the Alliance effectively, they have to be equipped with state-of-the-art technology. Defence research and technology uses the results of civil research in order to tackle specific defence issues; the funding for such research – also within the framework of international cooperation – is provided by the Federal Ministry of Defence.



In the field of defence research and technology, the Federal Republic of Germany depends on its *own R&D activities:* The departmental research of the Federal Ministry of Defence (BMVg) is indispensable for developing and assessing new weapons systems and for reviewing disarmament measures. At the same time, the BMVg's departmental research prepares the ground for the Federal Government's successful *international cooperation* in this sector. On the one hand, the Federal Government has to develop competitive concepts in order to be accepted as an equal partner. On the other hand, there is a need to pool limited research resources in view of the fact that the technology is more and more complex. Consequently, 70 % of the BMVg's large-scale projects are carried out in international cooperation.

Reducing costs through international division of labour

Close cooperation is required not only during the stage of product development; rather, it is already a necessity when new technologies are explored and their security policy impact is assessed. For this reason, the BMVg will continue to increase its involvement in international cooperation in the future: There are plans for *bilateral projects* – in particular with France – where the division of labour goes far beyond an exchange of information and experts. At the national level, the BMVg awards contracts for the *implementation of defence research* not only to defence-oriented research institutions but also to industry and to higher education institutions.

Eurofighter 2000: the largest development project

Currently the largest project in the field of defence development is the New European Fighter (Eurofighter 2000), which will be the successor to the Phantom F-4F. Another priority is the development of control and reconnaissance systems. The army's outdated armoured tube artillery will be replaced, and the command and control system will be modernised. In the air force, efforts are focused on tactical air defence, air transport, the armed forces' command and control capability, and the modernisation of the Tornado. For the navy, development efforts are made for surface and subsurface forces as well as for sea-based logistical support.

In addition, the Federal Armed Forces also carry out *medical and psychological defence research* in order to fulfil their humanitarian tasks in the fields of medical service and health care.

From research to testing

In its research activities, the BMVg distinguishes between

- research and technology (R&T), covering the period from research to the decision on a concrete project, and
- the actual development, which includes the definition and testing of a specific arms project.

The objective of defence R&T is to obtain assessments by experts – neutral, where possible – of the security situation and innovation processes, and to improve the performance standard of defence processes, technologies and systems.

Part V

International cooperation in research and technology

Contents

International cooperation in research and technology

Research without frontiers

In view of the markets of the future and the body of knowledge required for far-reaching innovations research and technology policy without international cooperation would be a torso. To be launched fundamental innovations need international standards; they are developed increasingly in an environment of global industrial cooperation as well as in a feedback process with nationally and internationally generated basic knowledge. To avoid misuse and to limit potential negative consequences new technologies need to be the subject of international regulations and agreements. For global environmental protection projects as well as for climate, polar and marine research programmes it is obvious anyway that knowledge and resources need to be pooled across national borders. High costs and investment risks alone make it increasingly difficult for individual countries to realise large-scale research plans and implement costly technology projects on their own, e.g. in the fields of space flight, high-energy physics or astronomy. For this reason the Federal Government invests in European and world-wide cooperation. In addition to the well-established European, transatlantic and German-Israeli partnerships which will be developed further, special attention is given to scientific and technological cooperation with the fast developing industrialised and newly industrialised countries in Asia and South America as well as with Central and East European countries and the successor states of the former Soviet Union which are going through a difficult transformation process.

The Federal Government and the research institutions and project management schemes it finances are members of more than 30 multilateral research organisations. They have concluded bilateral agreements on scientific and technical cooperation with over 50 countries.

International cooperation – for the benefit of all participants

Cooperation with other countries is not an end in itself. In international cooperative projects the Federal Government is rather pursuing quite specific objectives:

- to share cost, effort and risk involved in research projects,
- to contribute towards the process of European unification,
- to exchange scientific and technological findings and tackle global problems globally – also in scientific terms (e.g. in the environmental area),
- to support the transformation processes in Central and Eastern Europe and in the successor states of the former Soviet Union and their integration into European and world-wide R&T cooperation,
- to promote scientific and technological development of third world countries and newly industrialised countries through technology transfer, and to build cooperations,
- to strengthen the technological competitiveness of German industry and thus protect jobs.

Cooperation in Europe

The *Maastricht Treaty on European Union* has conferred a new dimension on Community promotion of research and technology (see box). EU funding schemes are so extensive today that they also have quite a significant impact on Germany with its diversified system of research funding by Federal and Länder governments and the business enterprise sector. In some areas this is particularly important. In *thermonuclear fusion research,* for example, member states not only coordinate all their activities, but also leave a substantial part of financing to the EU. In areas such as information technologies, industrial and materials technologies, non-nuclear energies, environmental and climate research as well as biotechnology the European component has gained considerable importance.

Fourth Framework Programme with a 13.1 billion ecu budget

The growing influence of the EU in research funding is not least reflected in increasing budget funds: Whereas the Third Framework Programme on Research (1990–1994) was funded with 6.6 billion ecus, the Fourth Framework Programme on Research (1994–1998) including the EURATOM Framework Programme has a budget of more than 13.1 billion ecus (some DM 24.5 billion). All schemes under the Third Framework Programme will be continued under the Fourth Framework Programme as well as the EURATOM Framework Programme. Newly launched programmes focus on targeted socio-economic priority research and transport research. Furthermore, funding schemes were integrated which previously used to be

handled outside the actual Framework Programme. Cases in point are THERMIE (energy demonstration programme) and SPRINT (funding of innovation and technology transfer).

There have been minor shifts in the allocation of funds: The sum earmarked for information and communications technologies which totalled more than DM 6 billion declined. Energy research has clearly gained in importance.

Maastricht: a new basis for R&D funding

The Maastricht Treaty has clearly given greater weight to Community research policy. What has remained unchanged is the goal to strengthen the scientific and technological basis of industry. At the same time, however, research funding has acquired new functions: Its responsibilities now include all political areas where the Community has competence, e.g. also health, environment and transport.

At the same time, the Treaty firmly enshrines the principle of subsidiarity, thus drawing clearer *limits* of Community action. Accordingly, the EU may only take action in those areas where the individual member states are not in a position to accomplish specific tasks. Examples in research policy are very large-scale research projects – such as research into controlled thermonuclear fusion, issues which are of particular importance for safeguarding Europe as an industrial production location as well as the development of European networks and policy areas of a transfrontier nature such as environmental research and the development of joint standards.

Furthermore, the Maastricht Treaty ensures a higher degree of transparency and facilitates better coordination within the Commission. Now all research activities are united under one umbrella, the *EU Framework Programme on Research.*

Another new feature is that many EU research programmes under the Fourth Framework Programme provide *special support for small and medium-sized enterprises* (SMEs). SMEs receive a grant towards feasibility studies when they have to formulate a project proposal or look for a partner. The EU also supports cooperations in the field of contract research: A minimum of four SMEs which are not affiliated, based in two different member states and have few or no research capacities of their own jointly contract out R&D work to a third party.

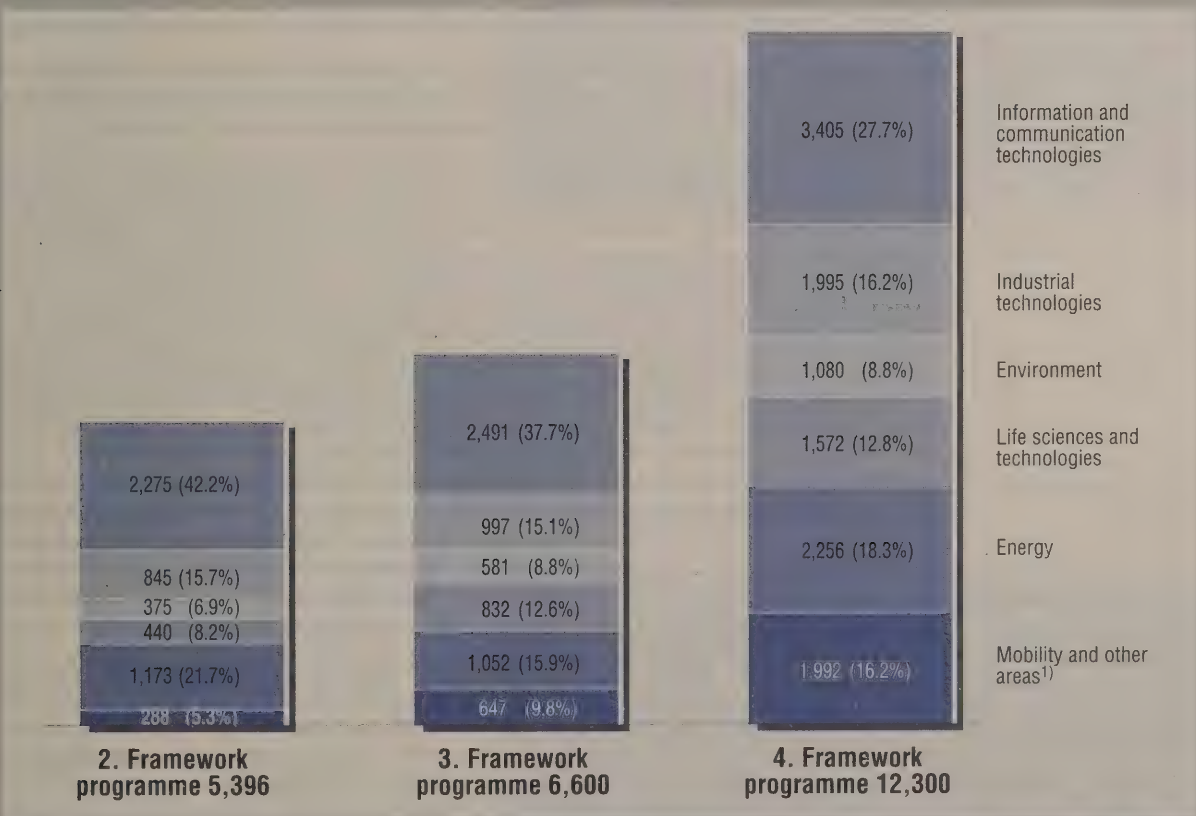
Assistance for SMEs

Figure V/1

Breakdown of finances in the framework programmes for RTD (EU)

Comparison of the 2. framework programme (1987 – 1991) – 3. framework pr. (1990 – 1996) – 4. framework pr. (1994 – 1998)

– shares in ecu million and % –



1) Incl. transport, international cooperation, dissemination and exploitation of research.

Source: European Commission and BMBF calculations

BMBF, BuFo 96

The Federal Government constructively contributed to formulating European research policy. The German position paper on the Fourth Framework Programme, for instance, helped ensure that EU R&D funding is limited to the pre-competitive

phase and focuses on specific programmes generating a European 'value added' and that the funds appropriated are used specifically for certain priority schemes, always taking into account the principle of subsidiarity.

During the German presidency of the Council of the European Union in the second half of 1994, the Federal Government launched new initiatives which were aimed, for instance, at coordinating research in Europe and improving application and funding procedures at the European Commission.

EUREKA – a trailblazer for cooperation in research and technology

A second pillar of European cooperation in research and technology is EUREKA, a technology initiative. Through EUREKA the member states intend to fund, coordinate and strengthen transfrontier cooperation among business enterprises and research institutions in application-oriented industrial projects. The objective is to create an effective European technology community, thus increasing Europe's competitiveness in the world market for new technologies.

At present 711 projects are underway with a financial volume of about DM 20 billion. The partners in cooperation are – mainly small and medium-sized – enterprises and research institutions of the currently 24 EUREKA member states and of the European Commission. As well as environmental technology and biotechnology the focal areas of cooperation include production engineering and transport technologies. In addition, EUREKA is more and more acting as a bridge to Central and Eastern European countries.

COST – flexible cooperation beyond EU borders

Following a third route European countries – including numerous non-EU member states – coordinate within the COST (European Cooperation in the Field of Scientific and Technical Research) framework research that is not directly market-oriented. This includes *basic research* as well as applied research in *areas not relevant to competition* such as meteorology, chemistry and telecommunications. Flexible cooperation within the COST framework is based on the principles of à-la-carte participation, financing at the national level and implementation in – currently more than 120 – concerted actions. COST plays a special role in the integration of Central and Eastern European researchers and the European-wide processing of new scientific themes.

ESA – European Space Agency

In the areas of *space research* and space technology multilateral cooperation focuses on the European Space Agency, ESA. The Federal Government intends to realise its space flight interests to the greatest possible extent within ESA.

The changed geopolitical situation and financial constraints in the ESA member states led progressively to a reorientation of European space activities in the field of manned space flight. The meeting of the ESA Council at ministerial level in Toulouse in October 1995 produced a breakthrough: With the COF laboratory module and the ATV transport vehicle Europe will make a visible and recognised contribution towards the International Space Station, the largest scientific cooperation programme world-wide (in which Russia will also participate). The original total cost ceiling of 3.9 billion ecus (as of late 1994) could be reduced to a current 2.8 billion ecus. At the same time the ministers emphasised how important it was for Europe to have independent access to space and decided to strengthen the competitiveness of the ARIANE 5 launcher through supporting programmes. The decisions on medium-term funding of the scientific programme and on the General Budget require ESA considerably to increase the efficiency of its work. The reorganisation of the ESA finance system based on the agreed introduction of the ecu will also bring about more clarity as well as considerable simplifications.

The EU, too, is playing an increasingly important role in space flight: On the one hand, it designs the regulatory framework, on the other it is an important buyer of products and services. This is why the Federal Government advocates to deepening the *cooperation between ESA and the EU.* To this end, working groups were set up to tackle themes like industrial policy and Earth observation, and contacts were established between the ESA Director General and the responsible EU commissioners.

EU and ESA: exemplary cooperation

Earth observation and navigation are two outstanding examples of the good cooperation between the EU and ESA. In the field of Earth observation both institutions are developing a joint strategy with EUMET-SAT; in the field of navigation they are jointly preparing a civil satellite navigation system, together with EUROCONTROL. Another important cooperation between the EU and ESA is CEO (Centres of Earth Observation). The objective of CEO is to develop a decentralised European data management and information system designed to process and provide remote sensing data for application by users. The Joint Research Agency of the European Commission is playing a crucial role in this system.

Earth observation and navigation are the most important parts of space flight studies within the Fourth EU Framework Programme on Research. The specific programme on the environment and climate has appropriated 100 million ecus for the development and utilisation of Earth observation technologies alone.

ESA is represented as an observer in important bodies of the EU Commission and vice versa. In addition, bilateral projects are implemented, especially with the USA, Russia and Japan.

As well as space research and space flight scientific *basic research* is another focus of German cooperation in European research organisations. Here again it is imperative to coordinate and pool budgets to avoid *duplication of work.* This is why European research institutions run internationally coordinated complex research programmes and large-scale equipment. Cases in point are German membership in CERN (high-energy physics) in Geneva, EMBC/EMBL (molecular biology) in Heidelberg, ESO (astronomy) near Munich as well as ILL and ESRF (neutron and synchrotron radiation) in Grenoble.

Pooling budget resources to reach the goal faster and at less cost

By involving scientifically and financially powerful non-member states like the USA, Japan and Canada a world-wide basis will be created for the first time for building and operating the 'Large Hadron Collider' (LHC) mega-project which CERN decided to implement in 1994. But nevertheless such a demanding and sophisticated project can only be realised if CERN can manage to achieve consistent savings elsewhere. This is why Germany successfully advocated defining posteriorities in the ongoing CERN programmes and projects. While the LHC is being built, this will result in savings in the total CERN budget of about CHF 1 billion.

The Synchrotron Radiation Facility, ESRF, was commissioned in 1994. The ILL very-high flux reactor – the most powerful neutron source world-wide – was overhauled and went on stream again in 1995.

In addition to the largely multilateral cooperative network in Western Europe the previously mainly bilateral *cooperation with Central and Eastern European countries* and the successor states of the former Soviet Union has become a new focus. *Changes in the political and economic system* in recent years have opened up numerous possibilities for cooperation. But the thorny path from a planned economy to a market economy system and to democracy also entails the symptoms of an economic and social crisis which affects scientific and technical cooperation. Cooperation in the traditional sense is not enough. In the process of restructuring their research systems Central and Eastern European countries as well as the successor states of the former Soviet Union depend on specific support.

Cooperation with the successor states of the former Soviet Union

It was demonstrated in numerous cases that in recent years cooperation with the states of the former Soviet Union has considerably gained in importance and intensity. This is corroborated by the following selected examples:

- On the basis of a bilateral agreement Germany cooperates in selected projects of the United Institute for Nuclear Research in Dubna/Russia which is funded by the successor states of the Soviet Union as well as Central and Eastern European states.
- Under its TRANSFORM programme the Federal Government finances contracts, among other things, which German research institutions award to groups of researchers in Russia and other successor states of the former Soviet Union. It also funds investment in the research infrastructure and enables scientists of that region to participate in European R&D networks.
- Two international organisations were set up to promote contacts and the exchange of scientists between Germany, among other countries, and the former Soviet Union. These organisations are the International Association for the Promotion of Cooperation with Scientists from the Independent States of the Former Soviet Union, INTAS, in Brussels and the International Science and Technology Centre in Moscow. Both organisations are supported by the Federal Government.

New focus: Central and Eastern Europe

The Federal Government endeavours to ensure that bilateral cooperation provides a mutual benefit. It also urges that Western multilateral forms of cooperation and organisation be opened up for Central and Eastern Europe and the former Soviet Union. In this way the countries of that region can integrate their potential – e.g. in space technology and thermonuclear fusion research – into European and international research projects. Cooperation with Russia in particular now comprises virtually all areas of natural and engineering sciences, covering basic research as well as technological and industry-related projects.

Cooperation outside Europe

Also *outside Europe* the Federal Government bases its cooperation both on bilateral agreements and on world-wide international organisations and institutions such as the UN, OECD, IAEA, UNESCO and CSD.

10 new R&D agreements since 1993

Bilateral agreements on cooperation, including *agreements concluded by government departments,* currently exist with about 50 countries. 10 of these agreements have been concluded since 1993. With this bilateral cooperation the Federal Government is pursuing two objectives:

- Cooperation with industrialised countries aims above all to *pool resources*, introduce a *division of labour* and exchange know-how.
- Cooperation with third world countries mainly involves newly industrialised countries; in addition to the objectives mentioned above, this cooperation is designed to establish a technology transfer to help *strengthen* technical and scientific capabilities in those regions. Furthermore, the demonstration of technological efficiency aims to make *market access for German industry* easier.

In October 1993 the Federal Government adopted its Asia concept and in May 1995 its concept for Latin America. With these concepts the government makes it clear that although international cooperation needs to be coordinated, it has to pay more attention to regional peculiarities. To specify these concepts the BMBF has submitted its own contributions related to both regions outlining the respective educational and research priorities of cooperation.

Multilateral R&D cooperation focuses mainly on projects in the areas of space research and technology (cooperation ESA/NASA), including satellite communications (INTELSAT), reactor safety, fuel cycle and nuclear material control (IAEA, OECD-NEA), thermonuclear fusion research (ITER), molecular biology and neurobiology (HFSPO, Strasbourg), global environmental research (WCRP, IGBP, HOP) and systems analysis (IIASA, Laxenburg near Vienna).

Regional priorities

Cooperation with countries outside Europe focuses on the following regions:

R&D cooperation contributes to peace in the Middle East

- In the Mediterranean region coperation with *Israel* has long since played an important role. To advance the peace process in the Middle East the Federal Government is increasingly cooperating in multilateral projects with Israel and its Arab neighbours. A first project was already launched in environmental research.

USA – most important partner in bilateral R&D cooperation

- The most intensive cooperation is that with the *USA*. A comparable level of technological development and shared social concepts make cooperation attractive for both sides. The exchange of scientists takes place at all levels and covers all disciplines. Research cooperation between universities, research institutions and industry has long since been a matter of course. Also in the field of government research policy the experience of the other partner is included in national considerations and new approaches are discussed with each other.
  The most outstanding areas covered by the about 50 cooperation agreements are space research and technology, energy technologies including reactor safety research as well as medical and geoscientific research.

East Asia – project cooperation in technologies for the future

- In the *East Asian region* scientific and technological cooperation with Japan and the newly industrialised countries is particularly important. The *Asia concept* developed by the BMBF provides for intensified project cooperation involving technologies for the future as well as an enhanced exchange in education and training. For instance, Germany offers attractive educational programmes for Asian students and scientists. Conversely, German industry and science are called upon to fund and honour stays of young scientists in Asia, especially Japan. In addition, the Federal Government, industry as well as science and intermediary organisations endeavour to coordinate their schemes more effectively.

Latin America – R&D cooperation involving industry

The Latin America concept submitted by the BMBF redefines the framework of cooperation in science, education, research and technology until the year 2000. The programme focuses on projects involving industry. The scope of exchange programmes will be considerably extended. International themes will play an important role in research and technology (e. g. marine and polar research, global environmental protection).

- *Latin America* offers major opportunities for German industry: Local markets are more open today, economic and financial policies are becoming more stable and numerous government enterprises are being privatised. These factors provide the basis of the BMBF's Latin America concept (see box).
- In 1992 the United Nations Conference on Environment and Development (UNCED) redefined the relationship with *third world countries*. The Federal Government is making an important contribution towards necessary scientific and technical development: In the energy sector, for example, it cooperates closely with developing countries, Central and Eastern European countries as well as the successor states of the former Soviet Union. The underlying objective of this coop-

eration is to develop and disseminate technologies which in the long term make as little use as possible of non-renewable resources and other environmental commodities and hence also contribute to global climate protection.

Resource-conserving technologies to meet third world needs

Another focus of cooperation is the use of renewable energy sources like water, sun and wind. Furthermore, bilateral departmental agreements were concluded with the environmental ministries of various countries (Singapore, Iran, Turkey, Indonesia, Israel, Mexico). These agreements are intended to support the transfer of know-how in environmental management and technology. By exchanging experts and organising joint technical meetings the partner countries gain more specific information on important issues like life cycle analysis and technology impact assessment, waste management, local environmental protection and the interaction between the environment on the one hand and industry, transport, agriculture and tourism on the other.

1. European cooperation

Transfrontier cooperation in Europe is growing: New treaties have created a clear legal basis for the EU's own research policy. But ever closer research networking is no longer limited to the EU only. Central and Eastern European countries as well as the states of the former Soviet Union are now also included in the pan-European transfer of science. The pooling of resources and know-how, funds and interests gives the continent a competitive edge in the global market and also contributes towards the process of European unification.

German participation in *cooperation in research and technology development* in Europe, especially with West European countries, takes place almost exclusively at the multilateral level; this cooperation can rely on a wide range of organisational forms and resources. It centres round the *Framework Programme on Research* of the European Union. For the period from 1995 to 1998 the EU allocates about DM 24.5 billion to transfrontier cooperations.

EU research funding is complemented by EUREKA, an open flexible framework for initiatives by business enterprises and application-oriented research institutions.

Cooperation under COST coordinates research in the member states, focusing on basic research, research in the pre-competitive phase and research that is in the public interest.

The *European Space Agency,* ESA, is responsible for European cooperation in space research and space technology. To fulfil this function the Agency has an annual budget of about DM 5 billion.

Research institutions financed by several member states were set up as an essential element of European science cooperation. These mainly include institutions dedicated to basic research such as the European Laboratory for Particle Research (CERN) and the European Southern Observatory (ESO). Other institutions provide special large-scale equipment for industry such as the European Synchrotron Radiation Facility (ESRF) for materials research and the European Transsonic Wind Tunnel (ETW) for optimising the aerodynamic properties of new aircraft. Both institutions started operation in recent years.

Bilateral cooperation in Europe focuses on cooperation with Central and Eastern Europe as well as the successor states of the former Soviet Union. The change in political and economic systems has provided a new thrust for scientific cooperation which the BMBF had supported for many years. Cooperation thus contributes towards *European integration* and brings the Central and Eastern European countries closer to the European Union.

1.1 European Union, European Commission
Rue de la Loi, 200, B-1049 Brussels

15 Member states: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, UK.

The Single European Act (1987) and the Treaty on European Union (1993) have provided a *clear legal basis* for the European Union to develop an R&D policy of its own. Accordingly, Community budget funds for R&D were increased considerably from 6.6 billion ecus (Third Framework Programme 1990 – 1994) to 13.1 billion ecus (Fourth Framework Programme 1994 – 1998). With about 4 % of the total budget, research and technology funding has become an important area within the Community.

Basis of research promotion in the European Union

The Treaty on European Union has given Community research policy a new dimension:

- The objective of the Community is to strengthen the scientific and technological bases of Community industry and to encourage it to be become more competitive at international level. This objective will remain unchanged. But above and beyond this, Community research funding is also meant to extend to other policy areas of the European Union. With this formulation taken from Article 130 f para 1 of the EC Treaty Community research funding and support in areas such as environment, energy and biosciences is also enshrined in the Treaty. As a result of this extended range of tasks, socio-economic research, for instance, is a new theme now covered by Community funding as well.
- The *Treaty of Maastricht* has united all Community activities in the areas of research, technological development and demonstration projects under the umbrella of a single programme, the *EU Framework Programme on Research*. The resulting integration increases transparency and improves coordination within the Commission itself.
- The *principle of subsidiarity* was enshrined in the Treaty on European Union as one of the elementary rules of the Community. Consequently, EU research funding must not duplicate national research promotion and funding. Rather, the Community is meant to become active in those areas where research would be to costly for individual member states so that it needs to be shifted to Community level. This applies especially to those large-scale research activities for which the EU member states can provide the necessary funds and the required scientific personnel only with great difficulties or not at all, e.g. in research on controlled thermonuclear fusion and in aeronautics. Community activities are also justified when because of their very nature they are defined as transfrontier activities, such as environmental, climate and marine research. This also applies to activities which are aimed at Community-wide standardisation, e.g. in the transport sector. And finally this also includes research themes where cooperation will generate "European value added", e.g. with regard to global competition.

In Community research policy *fundamental decisions* on research areas to be funded and the level of funds to be appropriated are taken jointly by the Council of the European Union and the European Parliament and set out in a *multiannual framework programme on research*. The framework programme defines the contents of the activities to be conducted in the various research areas such as information technologies and energy, and contains provisions relating to funding and promoting further activities under EU schemes. This includes in particular

- the promotion of cooperation with third countries and international organisations,
- the dissemination and exploitation of research results, and
- the training and mobility of researchers.

After consulting the European Parliament the Council will implement the framework programme by adopting *specific programmes* which provide the basis for calls for proposals and the allocation of funds to project participants (cf. below "Participation in Community research programmes").

With the *Joint Research Centre* (JRC) the Community has established its own large-scale research centre with eight institutes, four in Italy and the other four in Germany, the Netherlands, Belgium and Spain. At this Centre the Community conducts its own research in the form of so-called direct activities under the R&D programmes as well as research to provide scientific and technical support for other Community policies, especially in the areas of industrial and materials technologies, measurements and testing, environment, nuclear fission safety and controlled thermonuclear fusion. Furthermore, the JRC contributes to implementing the programme on the "Training and mobility of researchers" by offering scholarships and participating in scientific networks.

The JRC has a staff of more than 2,000. Taking a competition-driven approach it will in the future compete with research institutions in the member states when services for other Commission agencies are required in support of Community policies. For this reason total resources appropriated for the JRC under

the Fourth Framework Programme (total 1994 budget: 300 million ecus) were considerably reduced, compared with previous years.

Substance of Community research policy: the Fourth Framework Programme on Research

The currently valid Fourth Framework Programme on Research[1]) and the EURATOM Framework Programme[2]) entered into force in April 1994. They cover a period of five years (1994 to 1998) and have financial resources amounting to 13.1 billion ecus (about DM 24.5 billion).

Under German presidency of the Council of the European Union both framework programmes were translated into specific programmes without delay so that by December 1994 the Council and the European Parliament had taken all decisions necessary to ensure the continuity of European research funding after the Third Framework Programme on Research (1990 to 1994, financial resources: 6.6 billion ecus) had expired.

20 specific programmes

The two *framework programmes* comprise 20 *specific programmes.*

The area of *information and communications technologies* is divided into three programmes with a total budget of about 3.4 billion ecus:

- The *information technologies* programme (2,055 million ecus, plus 21 million ecus for research contracts awarded to the JRC) focuses on developing an information infrastructure to provide the basis for the information society of the future. Resources are appropriated for software technologies, basic technologies, multimedia technologies, high-performance computing, technologies for open microprocessor systems, technologies for business processes and manufacturing technologies.
- The *telematics* programme (899 million ecus) looks into the possibilities of linking modern telecommunications and information technologies to serve particular applications, taking special account of user needs. Research results can be applied in various areas, e.g. in administration, transport, education, information, health and the environment.
- The programme on *advanced communications technologies* (671 million ecus) aims to develop and test flexible, user-friendly, multimedia communications services. This will also include the integration of mobile telephony as well as continued digitisation and the improvement of networks and services. To this end, the necessary technological conditions need to be met by developing low-cost optical transmission technologies, optical switching and electronic and optical components. Thus the R&D activities provide the basis for the communications networks of the next century needed for high-speed data interchange.

Industrial technologies have a total budget of just under 1.9 billion ecus:

- The specific programme on *industrial and materials technologies* (1,722 million ecus, plus 96 million ecus for JRC work) is aimed at making the Community's manufacturing industry more competitive. The programme focuses on advanced manufacturing technologies, product innovation and transport technologies, especially aeronautical technologies. Special attention is given to multidisciplinary projects such as information technologies, telematics, measuring and testing, the environment, biosciences, non-nuclear energy and transport.
- Focusing on the further development and harmonisation of metrology as well as control and quality assurance processes and the mutual recognition of results, the new programme on *standards, measurements and testing* (184 million ecus, plus 123 million ecus for JRC work) has a dual objective: First, it is designed to expand the Single European Market and improve the cooperativeness of European companies. Second, in the area of state measuring and testing the programme is intended to prevent the import of prohibited substances, poor-quality products and products with misleading labelling. It is also aimed at efficiently implementing the joint European health care, environmental and industrial safety policies.

Environmental research has a budget of almost 1.15 billion ecus:

- The programme on *environment and climate* (567 million ecus, plus 340 million ecus for JRC activities) is intended to contribute to improving the quality of life as well as to achieving a sustainable and ecologically sound development in Europe. It focuses on climate changes and their impact on natural resources, the physics and chemistry of the atmosphere, environmental technologies, space technologies to be employed for environmental monitoring as well as socio-economic factors contributing to environmental changes.
- The focus of the programme on *marine sciences and technologies* (243 million ecus) is on ecological issues of marine sciences, the exploration of European coastal regions and marginal seas as well as the promotion of basic technologies for marine research and monitoring.

In the field of *biosciences* a total of about 1.7 billion ecus has been appropriated for activities under three specific programmes:

- The *biotechnology* programme (588 million ecus) implements the recommendations made in the European Commission's white paper by advancing this promising scientific field. The programme focuses on cell factories, genome analysis, plant and animal biotechnology, neurosciences, immunology and structural biology.
- The programme on *biomedicine and health* (358 million ecus) concentrates on studying severe and

[1]) Oficial Journal of the EC No. L 115, 6 May 1994.
[2]) Official Journal of the EC No. L 126, 18 May 1994.

widely spread diseases such as cancer, AIDS and other infectious diseases, cardiovascular disorders, work-related illnesses and environmental diseases as well as chronical diseases and ageing. Funds have also been appropriated for pharmaceutical research, biomedical technologies, brain research, genome research, health services research as well as medical ethics.

- The new programme on *agriculture and fisheries* (647 million ecus, plus 81 million ecus for JRC activities) covers all areas of research into agriculture and nutrition, forestry and fisheries. This programme offers particularly favourable opportunities for participation for the new Länder where agricultural research has traditionally been strong.

The programme on *non-nuclear energies* (1030 million ecus, plus 37 million for JRC work) looks into environmentally compatible, safe energy technologies with a view to contributing towards an ecologically sound energy supply. It is broken down into three main areas: renewable energies, rational use of energy and fossil energies.

The *transport* programme (256 million ecus) is intended to optimise rail transport networks, integrated transport chains, air transport, urban transport, waterborne transport and road transport. The aim is to develop a trans-European network integrating the various transport systems. The programme gives special attention to safety and environmental aspects. In addition, substantial funds have been appropriated for transport research under the telematics programme and the programme on industrial and materials technologies.

The new *targeted socio-economic research* programme (112 million ecus, plus 35 million ecus for JRC activities) is dedicated to studying the general setting of scientific and societal development. It is meant to improve the basis for political decision-making, thus contributing towards sustained and viable development in Europe. The main focus is on evaluating science and technology policy options, research on education and training as well as research on social integration and social exclusion in Europe.

The programme on *nuclear fission safety* (171 million ecus, plus 271 million ecus for JRC activities) intends to assess the overall risk of nuclear energy. Funds have been appropriated for the development of new nuclear safety concepts, reactor safety research (especially severe accidents), research and development work related to handling and storing radioactive waste and dismantling nuclear facilities, to the radiological impact on man and the environment as well as to coping with events of the past, e.g. the consequences of Chernobyl.

The programme on *controlled thermonuclear fusion* (846 million ecus, plus 49 million ecus for JRC work) unites all projects of the member states in the field of controlled thermonuclear fusion with magnetic plasma confinement. Its objective is the joint construction of safe and ecologically sound prototype fusion reactors. To achieve this end the programme focuses on three areas:

- development of detailed construction plans for an experimental reactor (next-step activities),
- investigations aimed at concept improvements in plasma physics and plasma technology (including the Wendelstein 7-X stellarator planned for Greifswald),
- technological R&D with a view to constructing a demonstration reactor.

The main objective of the new *international cooperation* programme (575 million ecus) is to promote cooperation with Central and Eastern Europe, the states of the former Soviet Union and developing countries. The programme also intends to establish cooperation with non-European industrialised countries and international organisations.

The *dissemination and exploitation of results* – now made into a programme in its own right (312 million ecus, plus 40 million ecus for JRC activities) – help optimise technology transfer beyond national borders. The programme also encourages the transfer of technologies to businesses, especially small and medium-sized enterprises, thus improving the innovative capacity of SMEs in general.

The programme on the *training and mobility of researchers* (792 million ecus) is a cross-disciplinary programme covering all fields of natural and engineering sciences and also the social sciences. The resources allocated are spent on research networks for the cooperation of laboratories and working groups from EU member countries as well as on scholarships for scientists, mainly postdoctoral researchers. Funds are also appropriated for visits by guest researchers to large research centres as well as for conferences at European level, awards for young scientists and seminars.

The two programmes for the Joint Research Centre (JRC) comprise those research activities which the JRC conducts with respect to the various specific programmes and which are financed from the total appropriations for these programmes:

- The *non-nuclear programme* (639 million ecus, plus 136 million ecus which the JRC can acquire by competing for research contracts with other research institutions in Europe) focuses on environment and climate, measurements and testing, materials research, agriculture and social science research.
- The *nuclear programme* (320 million ecus) focuses on nuclear safety (especially reactor safety), the safety of the nuclear fuel cycle and the safeguarding of fissionable material. The JRC also cooperates in the European thermonuclear fusion programme.

With its wide range of themes the Fourth Framework Programme on Research surpasses all its predecessors. This is primarily the result of the Maastricht Treaty with its extended chapter on research, as described above. Nevertheless, European research needs to be focused even more on themes offering genuine "European value added", thus enforcing the principle of subsidiarity (Cf. Part I for pertinent con-

siderations in the run-up to the drafting of the Fifth Framework Programme on Research).

Educational programmes SOKRATES and LEONARDO

Under the SOKRATES and LEONARDO DA VINCI programmes the EU encourages exchange in the fields of general (SOKRATES) and vocational education (LEONARDO). Both programmes run from 1995 to 1999. Their main objective is to improve European practical cooperation in this field. To a minor extent, both programmes also include research projects. They focus on preparing studies and analyses, organising expert meetings and colloquia as well as implementing pilot projects.

The focal themes are

- for SOKRATES:
  - Problems of young school drop-outs,
  - methods for assessing the quality of teaching;
- for LEONARDO:
  - Greater attraction of vocational training,
  - improved access of disadvantaged groups to vocational training,
  - forecasting skill requirements and qualification needs,
  - new types of initial and continuing education for vocational training staff.

The annual budgets for SOKRATES and LEONARDO are about 600,000 ecus and 4 million ecus, respectively. For further information apply to:

SOKRATES: Higher education sector: Deutscher Akademischer Austauschdienst (German Academic Exchange Service), Kennedyallee 50, D-53175 Bonn; school sector: Pädagogischer Austauschdienst, KMK-Sekretariat, Nassestrasse 8, D-53118 Bonn;

LEONARDO: Bundesinstitut für Berufsbildung (Federal Institut for Vocational Training), Fehrbelliner Platz 3, D-10707 Berlin.

Participation in Community research programmes

The rules for the participation in Community programmes of business enterprises, research institutions and higher education institutions were defined in a Council Resolution of November 1994[3]) According to these rules *transnational cooperation* is an indispensable criterion: A minimum of two institutions from at least two different member states have to cooperate in a project.

At regular intervals the Commission publishes calls for proposals for participation in specific programmes in the Official Journal. Applications are evaluated by external experts, the most important criterion being scientific quality.

The projects need to be application-oriented, yet have still to be at the pre-competitive stage. Another requirement is that it should be possible to use the results in as many industries and areas of application as possible.

As a matter of principle, projects selected for funding receive 50 % of costs incurred. As projects approach commercialisation this percentage may be reduced. Higher education institutions and other scientific institutions without any analytical receipt-expenditure accounting are entitled to receiving 100 % of the additional cost incurred.

EU research programmes are an important and necessary complement to national funding programmes. This is why the Federal Government supports information and consultancy for applicants from science and industry to ensure that projects with German participation are adequately considered in selection and allocation processes. So-called technical coordinators who are usually working with the BMBF project management agencies act as central national contacts for the various specific EU research programmes.

The extensive information and consultancy structures available in Germany also include the coordination unit for EU projects of German science organisations, research advisers at higher education institutions, Innovation Relay Centres and Euro-Info Centres as well as information centres established by industrial and trade associations.

Small and medium-sized businesses (SMEs) are an important economic factor in the member states of the European Union. This is why it is intended to intensify their participation in EU programmes. As a result the specific programmes under the Fourth Framework Programme include activities that are especially geared to SMEs:

These special activities for which a total of up to 770 million ecus has been appropriated mainly consist of grants for feasibility studies and contract research. Grants are awarded for *feasibility studies* so that a project proposal can be formulated and a partner can be selected. The grants cover up to 75 % of the cost incurred during the exploratory phase, with an SME being entitled to receive up to 22,500 ecus (about DM 41,000). *Contract research* is realised through cooperative R&D projects. In such a case at least four non-affiliated SMEs from two different member states which have only minor research capacities or none at all may award an R&D contract to a third party. Usually EU funding covers 50 % of the research cost. The procedures required for both activities are made easier by the fact that after the first invitation applications may be submitted any time and irrespective of any deadlines.

During its EU presidency the Federal Government worked to improve and simplify EU funding procedures. These efforts brought some important progress. In many specific programmes, for example, funding for SMEs was introduced. Another new feature is the possibility to apply a two-stage procedure

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[3]) Official Journal of the EC No. L 306/8, 30 June 1994.

for calls for proposals (an informal invitation to express interest prior to the actual formal call for proposals). Furthermore, participants in a project can choose whether they want to receive a lump-sum payment or be reimbursed for cost actually incurred.

Specific measures are taken to ensure better dissemination of research results and optimise their translation into marketable products. The Council of the European Union has established rules to protect intellectual property.[4]) To provide practical assistance as well, the Commission has set up a network of so-called Innovation Relay Centres in all member states. In order to ensure a better utilisation of findings interested parties receive targeted information on the results of pertinent EU research projects.

International cooperation of the European Union

To complement the international R&D cooperation in which its member states are engaged the EU collaborates with almost all third countries which have appreciable R&D capacities.

In addition to cooperation with European and non-European industrialised countries collaboration with Central and Eastern Europe, the new independent states of the former Soviet Union as well as developing countries has become a priority activity. In the future the Mediterranean countries will play a special role in cooperative schemes.

Apart from individual agreements the basis of R&D cooperation with third countries consists of rules and provisions for participation in programmes which are negotiated by the Commission and adopted by the Council:

- Institutions from all European countries, including the states of the former Soviet Union, may participate in individual projects under Community R&D programmes. Some of these R&D programmes also provide for participation on a project basis by institutions from non-European countries. Such participation in EU programmes, however, does not entitle these non-European institutions to receive any funding.
- Research institutions from the EEA states (Norway, Iceland, Liechtenstein) may participate under the same terms as EU member states since they contribute a certain share to financing the R&D programmes. A scientific and technical agreement was concluded with Israel which concedes to Israel a status comparable to that of an EEA state. It is conceivable that a similar arrangement will be worked out with Switzerland.
- The programme on "International cooperation" provides for and organises scientific and technical cooperation with third countries under the Fourth Framework Programme on Research. It defines the contents as well as the financial framework (540 million ecus) of this cooperation. The programme focuses on two financial priorities:
  - *Cooperation with Central and Eastern European countries and the successor states of the Soviet Union:* The research and development potential of these countries is to be stabilised through R&D activities and through the International Association for the Promotion of Cooperation with Scientists from the Independent states of the Former Soviet Union (INTAS). Another objective is to help theses countries solve their social, economic and environmental problems.
  - *Scientific and technical cooperation with developing countries:* This part of the programme intends to involve developing countries in the generation of know-how and the development of innovative technologies so as to enable them to solve their specific problems and ensure sustained economic development. Research activities focus on natural resources, agricultural production and health.

In addition, the specific programme on *international cooperation* provides funds required to ensure cooperation with other bodies of scientific and technological cooperation in Europe such as COST and EUREKA as well as with international organisations and institutions working in the scientific and technological area and with non-European industrialised countries.

Bodies of the European Union in the field of research

The Treaty on European Union granted the *European Parliament* a greater say in the field of research. As a result the Framework Programme – the most important issue to be decided upon under Community research policy – is adopted by the Council and by Parliament in a so-called co-decision procedure. Although Parliament has the right only to be heard in the case of specific programmes, the Council takes into account to the greatest possible extent the comments made by Parliament on specific programmes under the Fourth Framework Programme on Research. Parliament also plays an important role in drafting the Community's annual budget.

The member states are represented in the *Council of the European Union* within which the responsible ministers meet to discuss issues of research. Council decisions are prepared by the Research Group and the Permanent Representatives Committee.

The *European Commission* administers and implements the specific programmes. The member states participate in this process through their representatives in Programme Committees. In Germany the members of these Programme Commitees are appointed by the BMBF after consultation with other government departments. The Programme Committees decide, among other things, on work programmes, the contents of calls for proposals as well as projects proposed for funding by the Commission.

Member states have another possibility as well to participate in European research policy. The *Scientific and Technical Research Committee (CREST)*

[4]) Official Journal of the EC No. L 306/5, 30 November 1994.

whose members are high-ranking representatives of the member states deliberates on the substance of Community R&D policy, thus influencing strategic objectives and priorities. The comments drafted by CREST under the leadership of the Commission are not binding, but provide an important basis for decision-making by the Council and the Commission.

In 1994 the European Commission instituted the *European Science and Technology Assembly (ESTA)* to serve as its scientific adviser. The assembly is made up of 100 high-ranking scientists and representatives of business enterprises.

In addition, the Commission set up a *Space Advisory Group (SAG)* to support the Commission's activities in the field of space technologies. The group consists of representatives of the member states as well as observers from ESA and European user organisations. Important issues to be discussed by the group are a joint ESA/EU Earth observation strategy as well as the coordination of interests in the fields of telecommunications and navigation. The group also deals with questions of industrial policy. Through its cooperation in the SAG and in ESA the Federal Government is actively involved in the process of consultation and coordination between the two organisations.

1.2 Cooperation with Central and Eastern European countries and the successor states of the Soviet Union

In recent years cooperation with the countries in this region has been intensified continuously. The reasons to do so were the *political changes* and the lively exchange of information on potentials, priorities and perspectives of research and technology.

In this cooperation the Federal Government was not only striving to accomplish important research tasks for the mutual benefit of the partners involved. Its aim was also to support the partner countries in reorganising their research and technology systems and hence their *transition from a planned economy to a market economy and to democracy*. Germany is thus contributing to the integration of the region into the European and world-wide science community. There are various developments which document the progress made in this area:

- The admission of Hungary, the Russian Federation, Slovenia, Poland and the Czech Republic into EUREKA,
- the membership of Poland, Hungary, the Czech Republic and the Slovak Republic in COST since 1991 and of Slovenia and Croatia since 1992,
- the membership of many former Eastern bloc countries in, or their close contractual cooperation with, CERN as well as the cooperation of the USA, Russia and ESA in the International Space Station project.

Central and Eastern Europe

In most Central and Eastern European countries bilateral cooperation focuses on *reorganising research structures by setting up new or restructuring existing research institutions*. One example of successful cooperation is the Bay Zoltn Foundation in Hungary whose establishment was supported by Germany. The foundation is modelled on the Fraunhofer Society and so far has three institutes for applied, industry-related research. The initial phase of work at the institutes is supported through the funding of cooperative projects conducted by German Fraunhofer institutes together with Hungarian industry. In most countries of the region financial resources are rather scarce. This is why in the reorganisation of research structures in most cases existing research institutions are restructured, while new ones are founded only very rarely. In Poland and Romania, for instance, these restructuring measures are currently being supported by German experts acting as consultants.

German experience with setting up technology-based business incubators, especially in the new Länder, met with wide interest in Central and Eastern European countries. German experts acted as advisers to central and territorial governments, universities and potential founders of businesses in Hungary, the Slovak Republic, Poland, Romania, Latvia and Bulgaria. In these countries several technology-based business incubators are being built or in the preparatory phase.

The first phase of cooperation with Slovenia in assessing local research and technology potentials which was completed in 1995 has a pilot function. The objective of this cooperation is to define priorities, thus improving future competitive opportunities in the world market. In Hungary, the technology potentials of various sectors of Hungarian industry (e.g. medical technology) were studied with a view to creating appropriate local production facilities. It is intended to give to other Central and Eastern European countries, at their request, access to the methods applied to assess research and technology potentials available.

The *German Historical Institute in Warsaw* which was founded in 1993 promotes German-Polish cooperation in the humanities.

Successor states of the Soviet Union

Among the states of the former Soviet Union *Russia* is the largest and most important cooperation partner. Cooperation has grown considerably over the last three years. New fields such as laser technology, high-temperature superconduction, biotechnology, marine and polar research, environmental research, information and documentation complement the traditional fields of cooperation such as research in the areas of the peaceful uses of nuclear energy, health and agriculture as well as space research. Nowadays cooperation covers almost all areas of natural and engineering sciences, also comprising projects of basic research as well as of technological and industry-related research. As previously strictly shielded military research institutions are being opened, new possibilities of cooperation in pioneer areas emerge.

The foundations for cooperation with other states of the former Soviet Union have been laid, especially with *Ukraine, Belarus and Uzbekistan,* where a growing number of sophisticated projects are to be conducted.

Under its TRANSFORM programme the Federal Government is funding various projects:

- During a transitional period especially efficient groups of researchers in the former Soviet Union which are threatened by disintegration are supported through specific measures (e.g. government-financed contracts awarded by German research institutions);
- Projects aimed at improving the research infrastructure in these countries are funded (e.g. access to international science networks);
- Scientists in the region are enabled to participate in European and world-wide research and development networks.

The International Association for the Promotion of Cooperation with Scientists from the Independent States of the Former Soviet Union (INTAS) in Brussels and the International Science and Technology Centre in Moscow have a special significance for integration into the international science community. Both institutions which started work in 1993 and 1994, respectively, and implement complementary as well as national programmes are actively supported by the Federal Government. Within this framework intensive cooperative relations have developed between German scientists and their partners in the successor states of the former Soviet Union.

On the basis of a bilateral agreement Germany participates in selected activities of the *United Institute for Nuclear Research* in Dubna/Russia which is funded by successor states of the Soviet Union as well as Central and Eastern European countries. In this way the Federal Government supports the restructuring and integration of this outstanding institution into pan-European research.

2. World-wide cooperation

Germany is a member of numerous international organisations and research institutions. There are world-wide cooperations at all levels of research and in all research areas, ranging from nuclear energy to environmental and climate research to marine research. Bilateral cooperation with non-European countries makes it possible to select a particular partner for specific research projects and to base research work on an effective division of labour.

2.1 Cooperation with non-European countries and regions

Today scientific and technological cooperation with Western European countries usually takes place within the framework provided by the sophisticated multilateral forms of cooperation like the EU, EUREKA and ESA. The cooperation of the Federal Government with non-European countries, on the other hand, is largely based on bilateral agreements which are concluded either by the governments themselves or by subordinate research institutions. The advantages offered by this approach are the *simplified consultation procedure* and the possibility to take account of the *specific interests* and the *level of technological development* of the partners concerned.

The *selection of a specific partner* is guided by technological and political aspects and aims to achieve an effective division of labour as well as a pooling of resources. Bilateral cooperation between two countries may also fill free space which is sometimes not possible at the multilateral level. It is important that economic, research, educational and foreign policy aspects are coordinated within a homogeneous policy. Departmental aspects must not be pursued separately, but should rather complement each other.

2.1.1 Cooperation with the USA and Canada

Among the industrialised countries, the USA ranks first with about 50 cooperation agreements concluded with Germany. Joint programmes and projects focus on the following areas:

- *Space research and space flight technology,* especially the preparation of the International Space

Station and joint projects (X-SAR, SPAC, D 2, ROSAT, GALILEO),

- *energy technology*, especially safety aspects of nuclear energy,
- *medical research*, in particular cardiovascular diseases, cancer and public health research,
- *geoscientific research* (mutual deep-drilling programmes),
- *ground transport research* (local public passenger transport and high-speed transport technologies),
- *environmental research*, especially cleaning up contaminated sites.

In all areas of science and research, several thousands of government-financed visits by scientists and students to the partner country every year and a traditionally extensive exchange of information ensure that there is an enormously wide range of joint or complementary scientific work.

Acting as an additional intellectual bridge, the „*German-American Academic Council*" which strives to activate the existing scientific and human potential for mutual benefit started work in 1993. This institution where personalities from science, industry, politics and culture cooperate is funded by important science organisations in both countries. In addition, the *German Historical Institute (DHI) in Washington* provides a basis for the cooperation of German and US historians.

Cooperation with Canada has developed very well over the last 25 years and reached a consistently high level. It covers a wide range of scientific fields extending from pure basic research to application-oriented research. Cooperation focuses on the environment and environmental technologies, marine research, geosciences and information technology. There are also other cooperative projects, e.g. in space research, agriculture and forestry, physics and medical research.

In recent years cooperation was successfully extended to include *sectors important for industry* such as communications technology, materials sciences, production engineering and laser technology. New initiatives, e.g. in the field of production engineering, are being prepared.

The agreement on scientific and technological cooperation concluded between Canada and the EU will open up new complementary possibilities for bilateral cooperation as well.

2.1.2 Cooperation with Latin America

R&D cooperation with Latin America has so far been limited mainly to Brazil, Argentina, Chile and Mexico.

The most intensive cooperation is that with *Brazil*. The current legal basis of this cooperation is still provided by the framework agreement on scientific and technological cooperation of 1969 which was followed by a number of specific agreements.

On 20 March 1996 a new framework agreement was signed which provides for the involvement of Brazilian and German industry in this cooperation. After being ratified by the Brazilian Congress it will replace the 1969 agreement.

The BMBF cooperates with Brazil in the areas of environment, biotechnology, computer science, materials research, marine research, space flight and production engineering. The focus is on environmental research, including research into tropical ecosystems, energy, environmental technologies and heavy metals.

Cooperation with *Argentina* which is also based on a framework agreement on scientific and technological cooperation concluded in 1969 centres round environmental research in the broader sense, renewable energies, space flight, biotechnology and medical research as well as marine and polar research.

Scientific and technological cooperation with *Chile* also focuses on the environment and on space flight as well as – due to the favourable geographical location – on marine and Antarctic research.

Scientific and technological cooperation with Mexico is limited to a few projects focusing on environmental and medical research. Another objective of joint research work is to find answers to current questions of basic research.

Latin America concept of the BMBF

To specify the Latin America concept of the Federal Government of 17 May 1995, the BMBF took stock of cooperation in education, science, research and technology with Latin America and developed an integrated concept for future cooperation with that region. The BMBF defined the following objectives:

- To contribute to maintaining and developing the traditionally positive economic relations through intensified cooperation in education, research and technology;
- to extend important national research programmes through international cooperation, e.g. in marine and polar research and the geosciences;
- to intensify global environmental protection, especially by studying regional ecosystems and the climate;
- to improve cooperation with Latin America in the education sector.

Based on these objectives, and in view of past organically grown cooperation, specific measures are planned for the period between 1996 and 2000. The concept will be presented to the public in 1996.

2.1.3 Cooperation with Israel

Cooperation with Israel in basic and applied research has flourished for more than 30 years and is an outstanding highlight of bilateral relations. The pillars of cooperation are the German-Israeli Foundation for Scientific Research and Development (GIF) whose capital is to be doubled from DM 150 million to DM 300 million in the period from 1993 to 1996, as well as

the funding of German-Israeli cooperation centres through the Minerva-Stiftung Gesellschaft für die Forschung mbH and the research projects financed directly by the two national research ministries. Furthermore, a Cooperation Council for High and Environmental Technologies was instituted which is expected to intensify scientific and technological relations between the two countries in the industrial sector.

2.1.4 Cooperation with industrialised and newly industrialised countries in Asia

Cooperation between the BMBF and Asian countries is – in some cases – based on more than 20 years of experience. Irrespective of their classification as industrialised countries, newly industrialised countries or developing countries, many of these states can boast outstanding groups of highly qualified scientists, excellently equipped laboratories and dynamic technological development. This is why cooperation with Asia based on a give-and-take relationship is of particular interest also for Germany.

East Asia is still dominated by *Japan's* outstanding position. Japan continues to have large export surpluses vis-à-vis the tiger economies of Korea and Taiwan and is pursuing long-term strategies to establish industrial cooperation with virtually all countries in the Asian region. It is particularly interested in international contacts in the area of basic research, especially with the USA, but also with other industrialised countries.

As early as 1974 the governments of Japan and Germany concluded an agreement on *cooperation in science and technology*. Cooperation focuses on information sciences and biosciences, high-energy physics, environmental research and, above all, space research. Germany and Japan cooperate closely in forecasting long-term technological trends (Delphi studies).

The German-Japanese Cooperation Council for High and Environmental Technologies was instituted in 1994 to promote bilateral relations especially in industry-driven cooperation. It is composed of high-ranking representatives, especially from the industry sector. The Council's third meeting will take place in Tokyo in May 1996.

The *German Institute for Japanese Studies (DIJ)* in Tokyo concentrates its work on studying modern Japan and German-Japanese relations.

Cooperation with *Indonesia* was continuously developed further. Energy research is still a focus of this cooperation: Studies concentrate on the use of alternative energy sources, especially solar energy. The future of German-Indonesian cooperation in the field of renewable energies will be shaped by the ELDORADO programme which is characterised by the broad-based demonstration of mature technologies. They cover in particular the supply of individual houses with photovoltaic power for lighting and radio as well as solar-powered pumps to replace diesel-driven pumps. Another focus is biotechnology. The biotechnical disposal of abattoir wastes is the technologically most advanced project. The prototype plant was transferred to the government research centre where it is now used to study the disposal of agricultural wastes.

German cooperation with *Korea* mainly focuses on joint activities in basic research, the exchange of experience in energy research as well as the exchange of scientists. An important sign of intensified cooperation is an agreement concluded between the Alexander von Humboldt Foundation and the Korea Science and Engineering Foundation (KOSEF) under which KOSEF will allocate an annual $ 1 million to exchange programmes over the next five years. Comparable funds will be appropriated by the institutions involved on the German side (Alexander von Humboldt Foundation, Max Planck Society, German Research Foundation). Under the agreement, German and Korean institutes will be twinned. In addition, Korea will set up a special institute in Saarbrücken dedicated to environmental studies.

Scientific and technological cooperation with the *People's Republic of China* is based on an intergovernmental agreement concluded as early as 1978. It was followed by further agreements relating to particular research areas. Focuses of research policy have been basic research and the exchange of scientists. In this way important personal contacts were established over the years; a basis of trust was created which now needs to be used for further development. Other priorities are research relating to global provision for the future and application-oriented research to support industrial activities. The conclusion of an agreement between DARA and the Chinese Space Agency created the basis for intensive *cooperation in the space sector*. The large number of agreements was complemented on the occasion of the Federal Chancellor's visit in November 1995 by a cooperation agreement concluded between the German Research Foundation and the Chinese National Natural Science Foundation. Both governments also agreed to set up a dialogue forum on high technology.

Every eighteen months the German-Chinese commission on scientific and technological cooperation takes stock of ongoing cooperative work and decides on the inclusion of additional projects. Technical steering committees regularly complement the coordination of cooperation.

2.1.5 Cooperation with developing countries

The world is characterised by increasing interdependencies and the *globalisation* of technology development on the one hand and by a *wide gap between developing and industrialised* countries on the other. Science, research and technology are today confronted with the challenge to develop concepts – beyond national borders – for solving shared problems as well as the problems of the third world. This is not only in keeping with the principle of solidarity, but also results from the shared responsibility for the peaceful coexistence of nations.

Asia concept of the BMBF

Asia-Pacific – the countries in South-East Asia as well as Japan, China, Korea and India – is becoming more and more important. In order to intensify cooperation with this region and provide a broader conceptual basis, the BMBF in October 1995 presented the educational and research policy priorities of its Asia concept for cooperation with countries in Asia-Pacific.

The concept pursues the following objectives:

- To create a better understanding of the dynamic development in Asia-Pacific, especially in science, technology and innovation, and educate the German public accordingly;
- to bring Germany's industrial, scientific and technological capacities together with the possibilities and needs of those countries so as to contribute to developing their scientific and technological potential;
- to offer suitable schemes to meet the great demand for qualified educational services in those countries as this is an important element in cultivating economic, scientific and cultural relations;
- to strengthen the shared awareness of ecological risks and jointly develop technological and economic solutions to open up those markets.

In this spirit the Federal Government has set itself the task to advance the capabilities of third world countries and hence their *development and prosperity* through scientific and technological cooperation. Total funds appropriated by the BMBF for ongoing projects with developing countries amount to about DM 330 million. These projects which also have specific research objectives complement the development schemes of the Federal Ministry for Economic Cooperation which support, among other things, the development and improvement of a scientific and technological infrastructure (higher education, technology centres, research institutes) in the developing countries.

BMBF activities are aiming in particular to extend national research programmes, provide access for German industry and train internationally experienced, skilled manpower by

- developing and testing new technologies for use in developing countries,
- adapting processes and technologies commonly applied in industrialised countries to the conditions prevailing in the respective partner country, as well as
- transferring scientific and technological knowledge to strengthen the R&D capacities and economic performance and competitiveness of the developing countries.

Funding and support focus on the following priorities:

Energy research and energy technology: Most important are the utilisation of renewable energies – which in fact is the most extensive field of cooperation with developing countries – as well as coal technology. Cooperation in nuclear technology plays only a minor role today and centres on issues of safety engineering.

Projects relating to the utilisation of solar and wind energy receive priority funding. These projects focus on developing, testing and adapting photovoltaic systems and wind generators for drying, cooling, air-conditioning, for pumping water and for decentralised electricity generation in rural areas.

In environmental research the *study of tropical ecosystems* is becoming more and more important. The projects aim to deepen the knowledge of the mechanisms of action within ecologically important biosystems and develop concepts for their ecologically sound utilisation. In addition, they are intended to improve environmental management strategies and environmental protection in the partner countries.

Cooperation in the field of environmental technologies focuses on developing and adapting low-emission technologies for use in developing countries. Important activities are the development of ecologically sound manufacturing processes, sewage and waste treatment as well as studies of soil and air pollution.

Biotechnological cooperation with developing countries is also rapidly gaining in significance. The main areas of cooperation will include the investigation and control of tropical diseases, microbial treatment of sewage and waste, plant breeding, biochemical production processes for food and luxury goods as well as the extraction of active plant ingredients for medical drugs.

Cooperation with coastal countries in the third world in the field of *marine research* primarily intends to collect data relating to the conditions required for utilising marine resources as well as to problems of the marine environment.

In addition, Germany has for several years supported training courses on *extraterrestrial and planetary research* organised jointly by the UN and ESA.

Part VI

Promotion organisations and research institutions in the Federal Republic of Germany

– Extract from research addresses –

1. Promotion organisations

Deutsche Forschungsgemeinschaft e. V. (DFG)
53175 Bonn, Kennedyallee 40
Tel.: 02 28/8 85-1, Fax: 02 28/8 85-22 27

Deutscher Akademischer Austauschdienst (DAAD)
53175 Bonn, Kennedyallee 50
Tel.: 02 28/8 82-0, Fax: 02 28/8 82-4 44

Alexander von Humboldt-Stiftung (AvH)
53173 Bonn, Jean-Paul-Straße 12
Tel.: 02 28/8 33-0, Fax: 02 28/8 33-1 99

Stifterverband für die Deutsche Wissenschaft
45239 Essen, Barkhovenallee 1
Tel.: 02 01/84 01-0, Fax: 02 01/84 01-3 01

Volkswagen-Stiftung
30519 Hannover, Kastanienallee 35
Tel.: 05 11/83 81-0, Fax: 05 11/83 81-3 44

Deutsche Bundesstiftung Umwelt (DBU)
49090 Osnabrück, An der Bornau 2
Tel.: 05 41/96 33-0, Fax: 05 41/96 33-1 90

Stiftung CAESAR (Center of Advanced European Studies and Research)
53177 Bonn, Kurfürstenallee 23
Tel.: 02 28/57-0

Arbeitsgemeinschaft industrieller Forschungsvereinigungen (AiF) „Otto von Guericke" e. V. (AiF)
50968 Köln, Bayenthalgürtel 23
Tel.: 02 21/3 76 80-0, Fax: 02 21/3 76 80-27

2. Supporting organisations

2.1 Max-Planck-Gesellschaft zur Förderung der Wissenschaften e. V. (Max Planck Society for the Advancement of Science) (MPG)
80539 München, Hofgartenstraße 2
Tel.: 0 89/21 08-0, Fax: 0 89/21 08-11 11

Research institutions of the Max-Planck-Gesellschaft and working groups at universities

Max-Planck-Institut für Aeronomie
37191 Katlenburg-Lindau, Max-Planck-Straße 2
Tel.: 0 55 56/9 79-0, Fax: 0 55 56/9 79-2 40

Max-Planck-Institut für Astronomie
69117 Heidelberg, Königstuhl 17
Tel.: 0 62 21/5 28-0, Fax: 0 62 21/5 28-2 46
Außenstelle: Spanien

Max-Planck-Institut für Astrophysik
85748 Garching, Karl-Schwarzschild-Straße 1
Tel.: 0 89/32 99-00, Fax: 0 89/32 99-32 35

Bibliotheca Hertziana – Max-Planck-Institut
I-00187 Rom, 28 via Gregoriana, Palazzo Zuccari
Tel.: 00 39-6/6 99 93-1, Fax: 00 39-6/6 99 93-3 33

Max-Planck-Institut für Bildungsforschung
14195 Berlin, Lentzeallee 94
Tel.: 0 30/8 29 95-1, Fax: 0 30/8 24 99 39

Max-Planck-Institut für Biochemie
82152 Martinsried bei München, Am Klopferspitz 18 a
Tel.: 0 89/85 78-1, Fax: 0 89/85 78-37 77

Max-Planck-Institut für Biologie
72076 Tübingen, Spemannstraße 2
Tel.: 0 70 71/6 01-7 50, Fax: 0 70 71/6 01-7 59

Max-Planck-Institut für Biophysik
60596 Frankfurt/Main, Kennedyallee 70
Tel.: 0 69/63 03-1, Fax: 0 69/63 03-2 44

Max-Planck-Institut für Chemie (Otto-Hahn-Institut)
55128 Mainz, Joh.-Joachim-Becher-Weg 27
Tel.: 0 61 31/3 05-0, Fax: 0 61 31/3 05-3 88

Max-Planck-Institut für biophysikalische Chemie (Karl-Friedrich-Bonhoeffer-Institut)
37077 Göttingen, Am Faßberg
Tel.: 05 51/2 01-0, Fax: 05 51/20 16-12 22

Max-Planck-Institut für Eisenforschung GmbH
40237 Düsseldorf, Max-Planck-Straße 1
Tel.: 02 11/67 92-1, Fax: 02 11/67 92-2 68

Max-Planck-Institut für experimentelle Endokrinologie
30625 Hannover, Feodor-Lynen-Straße 7
Tel.: 05 11/53 59-0, Fax: 05 11/53 59-2 03

Max-Planck-Institut für Entwicklungsbiologie
72076 Tübingen, Spemannstraße 35
Tel.: 0 70 71/6 01-1, Fax: 0 70 71/6 01-3 00

Max-Planck-Institut für Festkörperforschung
70569 Stuttgart, Heisenbergstraße 1
Tel.: 07 11/6 89-0, Fax: 07 11/6 89-10 10
Außenstelle: Hochfeld-Magnetlabor Grenoble

Friedrich-Miescher-Laboratorium für biologische Arbeitsgruppen in der Max-Planck-Gesellschaft
72076 Tübingen, Spemannstraße 37-39
Tel.: 0 70 71/6 01-4 60, Fax: 0 70 71/6 01-4 55

Locations of institutions of the Max Planck Society
in Germany

Source: BMBF (as of January 1996)

BMBF, BuFo '96

Fritz-Haber-Institut der Max-Planck-Gesellschaft
14195 Berlin, Faradayweg 4-6
Tel.: 0 30/84 13-30, Fax: 0 30/84 13-31 55

Max-Planck-Institut für molekulare Genetik
14195 Berlin, Ihnestraße 73
Tel.: 0 30/84 13-0, Fax: 0 30/84 13-13 88

Max-Planck-Institut für Geschichte
37073 Göttingen, Hermann-Föge-Weg 11
Tel.: 05 51/49 56-0, Fax: 05 51/49 56-70

Max-Planck-Institut für Gesellschaftsforschung
50677 Köln, Lothringer Straße 78
Tel.: 02 21/3 36 05-0, Fax: 02 21/3 36 05-55

Gmelin-Institut für anorganische Chemie und Grenzgebiete der Max-Planck-Gesellschaft
60486 Frankfurt/Main, Varrentrappstraße 40-42
Tel.: 0 69/79 17-1, Fax: 0 69/79 17-3 38

Max-Planck-Institut für Gravitationsphysik
(endgültiger Standort Golm b. Potsdam)
14473 Potsdam, Schlaatzweg 1
Tel.: 03 31/2 75 37-0, Fax: 03 31/2 75 37-98

Max-Planck-Institut für Hirnforschung
60528 Frankfurt/Main, Deutschordenstraße 46
Tel.: 0 69/9 67 69-0, Fax: 0 69/9 67 69-4 33

Forschungsstelle für Humanethologie in der Max-Planck-Gesellschaft (bis 30. 6. 1996)
82346 Andechs, Von-der-Tann-Straße 3-5
Tel.: 0 81 52/3 73-59, Fax: 0 81 52/3 73-70

Max-Planck-Institut für Immunbiologie
79108 Freiburg, Stübeweg 51
Tel.: 07 61/51 08-0, Fax: 07 61/51 08-2 21

Max-Planck-Institut für Infektionsbiologie
10117 Berlin, Monbijoustraße 2
Tel.: 0 30/28 02-62 10, Fax: 0 30/28 02-62 12

Max-Planck-Institut für Informatik
66123 Saarbrücken, Im Stadtwald
Tel.: 06 81/3 02-54 10, Fax: 06 81/3 02-54 01

Max-Planck-Institut für Kernphysik
69117 Heidelberg, Saupfercheckweg 1
Tel.: 0 62 21/5 16-1, Fax: 0 62 21/5 16-5 40

Max-Planck-Institut für Kohlenforschung (rechtsfähige Stiftung)
45470 Mülheim/Ruhr, Kaiser-Wilhelm-Platz 1
Tel.: 02 08/3 06-1, Fax: 02 08/3 06-29 80

Max-Planck-Institut für Kolloid- und Grenzflächenforschung (derzeit mit Teilstandorten in Berlin und Teltow, endgültiger Standort Golm b. Potsdam)
a) 12489 Berlin, Rudower Chaussee 5, Haus 9.9
   Tel.: 0 30/63 92-31 00, Fax: 0 30/63 92-31 02
b) 14513 Teltow, Kantstraße 55
   Tel.: 0 33 28/46-2 16, Fax: 0 33 28/46-2 15

Max-Planck-Institut für biologische Kybernetik
72076 Tübingen, Spemannstraße 38
Tel.: 0 70 71/6 01-5 01, Fax: 0 70 71/6 01-5 75

Max-Planck-Institut für Limnologie
24306 Plön, August-Thienemann-Straße 2
Tel.: 0 45 22/7 63-1, Fax: 0 45 22/7 63-3 10

Max-Planck-Institut für Mathematik
53225 Bonn, Gottfried-Claren-Straße 26
Tel.: 02 28/4 02-0, Fax: 02 28/4 02-2 77

Max-Planck-Institut für Mathematik in den Naturwissenschaften (in Gründung) Leipzig
Max-Delbrück-Laboratorium in der Max-Planck-Gesellschaft
50829 Köln, Carl-von-Linné-Weg 10
Tel.: 02 21/50 62-6 01, Fax: 02 21/50 62-6 13

Max-Planck-Institut für experimentelle Medizin
37075 Göttingen, Hermann-Rein-Straße 3
Tel.: 05 51/38 99-0, Fax: 05 51/38 99-3 88

Max-Planck-Institut für medizinische Forschung
69120 Heidelberg, Jahnstraße 29
Tel.: 0 62 21/4 86-0, Fax: 0 62 21/4 86-3 51

Max-Planck-Institut für Metallforschung
a) **Teilinstitut für Physik**
   70569 Stuttgart, Heisenbergstraße 1
   Tel.: 07 11/6 89-0, Fax: 07 11/6 89-10 10
b) **Teilinstitut für Werkstoffwissenschaft**
   70174 Stuttgart, Seestraße 92
   Tel.: 07 11/20 95-1, Fax: 07 11/2 26 57 22

Max-Planck-Institut für Meteorologie
20146 Hamburg, Bundesstraße 55
Tel.: 0 40/4 11 73-0, Fax: 0 40/4 11 73-2 98

Max-Planck-Institut für marine Mikrobiologie
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01326 Dresden, Krügerstraße 22
Tel.: 03 51/3 74 82-0, Fax: 03 51/3 74 82-18

Fraunhofer-Anwendungszentrum für Verarbeitungsmaschinen und Verpackungstechnik (AVV) des Fraunhofer-Instituts für Lebensmitteltechnologie und Verpackung (ILV)
Technische Universität Dresden
01062 Dresden, Mommsenstraße 13
Tel.: 03 51/4 63-47 46, Fax: 03 51/4 63-71 42

Sachsen-Anhalt/Saxony-Anhalt

Fraunhofer-Institut für Fabrikbetrieb und -automatisierung (IFF)
39104 Magdeburg, Elbstraße 3-5
Tel.: 03 91/40 90-0, Fax: 03 91/40 90-3 45

Fraunhofer-Institut für Werkstoffmechanik (IWM)
Außenstelle für Mikrostruktur von Werkstoffen und Systemen (EMWS)
06120 Halle/Saale, Heideallee 19
Tel.: 03 45/5 58 81-0, Fax: 03 45/5 51 12 91

Schleswig-Holstein

Fraunhofer-Institut für Siliziumtechnologie (ISiT)
Itzehoe (im Bau)
z. Z. 14199 Berlin, Dillenburger Straße 53
Tel.: 0 30/8 29 98-0, Fax: 0 30/8 29 98-1 99

Thüringen/Thuringia

Fraunhofer-Einrichtung für Angewandte Optik und Feinmechanik (IOF)
07745 Jena, Schillerstraße 1
Tel.: 0 36 41/5 82-0, Fax: 0 36 41/5 29 64

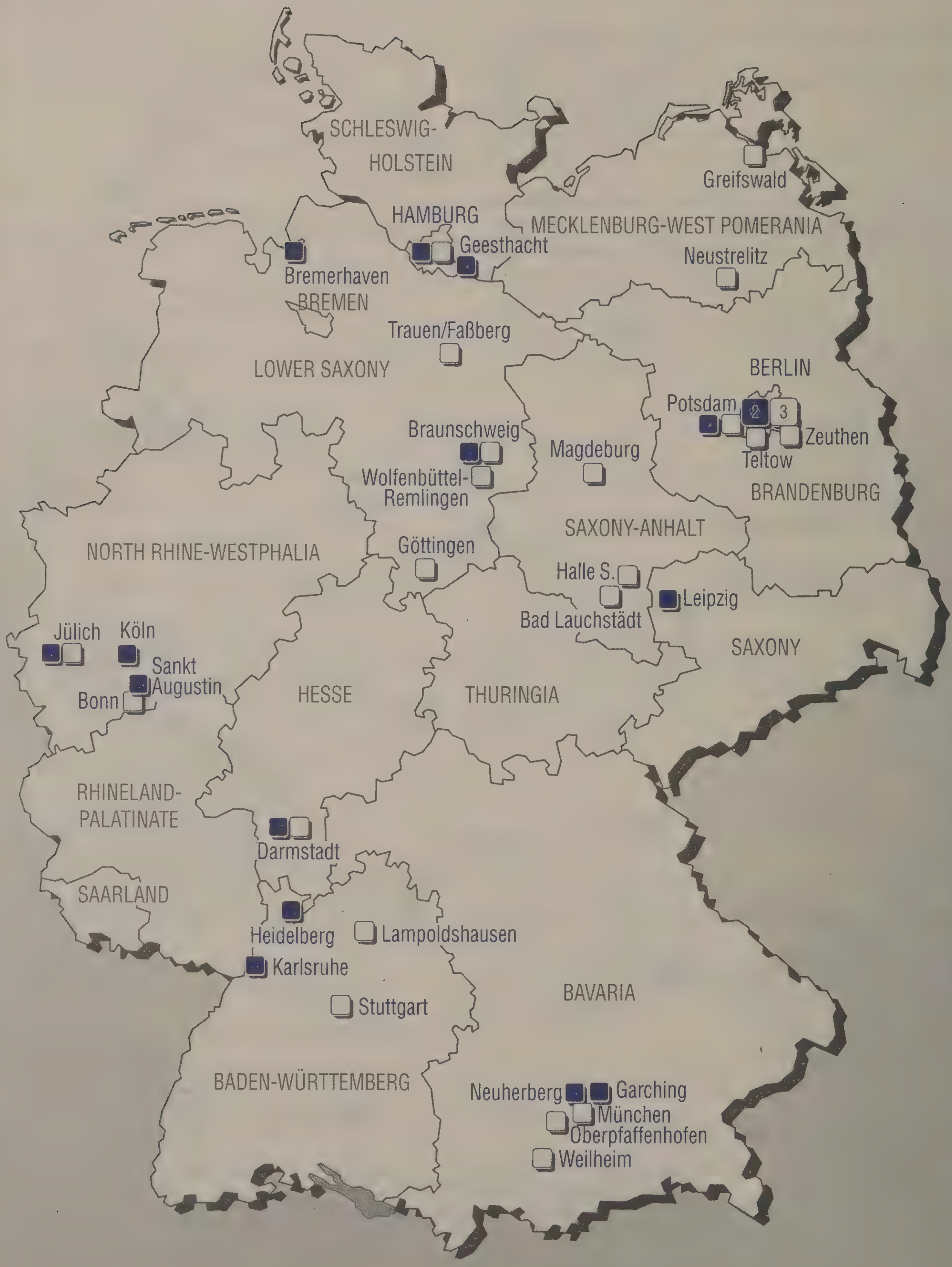
Fraunhofer-Anwendungszentrum für Systemtechnik (AST) des Fraunhofer-Instituts für Informations- und Datenverarbeitung (IITB)
Technische Universität Ilmenau
98684 Ilmenau, Am Ehrenberg
Tel.: 0 36 77/69-0, Fax: 0 36 77/69-17 01

Locations of institutions of the Fraunhofer Society
in Germany

Source: BMBF (as of January 1996)

BMBF, BuFo '96

Locations of national research centres
in Germany



Main location
Branch institute
4 Number of institutions (2 or more)

Source: BMBF (as of January 1996)

BMBF, BuFo '96

3. National research centres

Stiftung Alfred-Wegener-Institut für Polar- und Meeresforschung (AWI)
27568 Bremerhaven, Columbusstraße
Tel.: 0471/4831-0, Fax: 0471-4831-149, Telex: 238695 polar d

Stiftung Deutsches Elektronen-Synchrotron (DESY)
22603 Hamburg, Notkestraße 85
Tel.: 040/8998-0, Fax: 040/8998-3282, Telex: 215124 (desy)

Stiftung Deutsches Krebsforschungszentrum (DKFZ)
69120 Heidelberg, Im Neuenheimer Feld 280
Tel.: 06221/42-0, Fax: 06221/42-2995

Deutsche Forschungsanstalt für Luft- und Raumfahrt e. V. (DLR)
51147 Köln, Linder Höhe
Tel.: 02203/601-0, Fax: 02203/67310

Gesellschaft für Biotechnologische Forschung mbH (GBF)
38124 Braunschweig, Mascheroder Weg 1
Tel.: 0531/6181-0, Fax: 0531/6181515, Telex: 952667 (gibio d)

Stiftung Geo-Forschungs-Zentrum Potsdam (GFZ)
14473 Potsdam, Telegrafenberg
Tel.: 0331/288-0, Fax: 0331/228-1002

GKSS-Forschungszentrum Geesthacht GmbH (GKSS)
21502 Geesthacht, Max-Planck-Straße
Tel.: 04152/87-0, Fax: 04152/871618

GMD-Forschungszentrum Informationstechnik GmbH
53754 Sankt Augustin, Postfach 1316, Schloß Birlinghoven
Tel.: 02241/14-0, Fax: 02241/14-2889, Telex: 889469 gmd d

GSF-Forschungszentrum für Umwelt und Gesundheit GmbH
85764 Neuherberg, Ingolstädter Landstraße 1
Tel.: 089/3187-0, Fax: 089/3187-3322, Telex: 523125 stral d

Gesellschaft für Schwerionenforschung mbH (GSI)
64291 Darmstadt, Planckstraße 1
Tel.: 06151/359-1, Fax: 06151/359-785, Telex: 0419593

Hahn-Meitner-Institut Berlin GmbH (HMI)
14109 Berlin, Glienicker Straße 100
Tel.: 030/8062-0, Fax: 030/8062-2181, Telex: 185763 hmi d

Max-Planck-Institut für Plasmaphysik (IPP)
85748 Garching bei München, Boltzmannstraße 2
Tel.: 089/3299-01, Fax: 089/3299-2200

Forschungszentrum Jülich GmbH (KFA)
52425 Jülich
Tel.: 02461/61-0, Fax: 02461/615327, Telex: 833556 kfa d

Forschungszentrum Karlsruhe GmbH (FZK) Technik und Umwelt
76021 Karlsruhe, Postfach 3640
Tel.: 07247/82-0, Fax: 07247/82-5070

Stiftung Max-Delbrück-Centrum für Molekulare Medizin (MDC)
13125 Berlin-Buch, Robert-Rössle-Straße 10,
Tel.: 030/94060, Fax: 030/9494161

UFZ – Umweltforschungszentrum Leipzig-Halle GmbH
04318 Leipzig, Permoserstraße 15
Tel.: 0341/235-0, Fax: 0341/235-2791

4. Institutions on the „Blue List" promoted jointly by the Federal and Länder governments by Länder

Baden-Württemberg

Deutsches Institut für Fernstudienforschung an der Universität Tübingen (DIFF)
72072 Tübingen, Konrad-Adenauer-Straße 40, Postfach 1569
Tel.: 07071/979-0, Fax: 07071/979-100

Fachinformationszentrum Karlsruhe, Gesellschaft für wissenschaftlich-technische Information mbH (FIZ Ka)
76344 Eggenstein-Leopoldshafen
Tel.: 07247/808-606, Fax: 07247/808-666

Gesellschaft Sozialwissenschaftlicher Infrastruktureinrichtungen e. V. (GESIS) c/o Zentrum für Umfragen, Methoden und Analysen e. V. (ZUMA)
(Vereinssitz)
68072 Mannheim, Postfach 122155
Tel.: 0621/18004-0, Fax: 0621/18004-49

Institut für deutsche Sprache (IDS)
68061 Mannheim, R 5, 6–13
Tel.: 0621/1581-0, Fax: 0621/1581-200

Kiepenheuer-Institut für Sonnenphysik (KIS)
79104 Freiburg, Schöneckstraße 6
Tel.: 0761/31980, Fax: 0761/3198-111

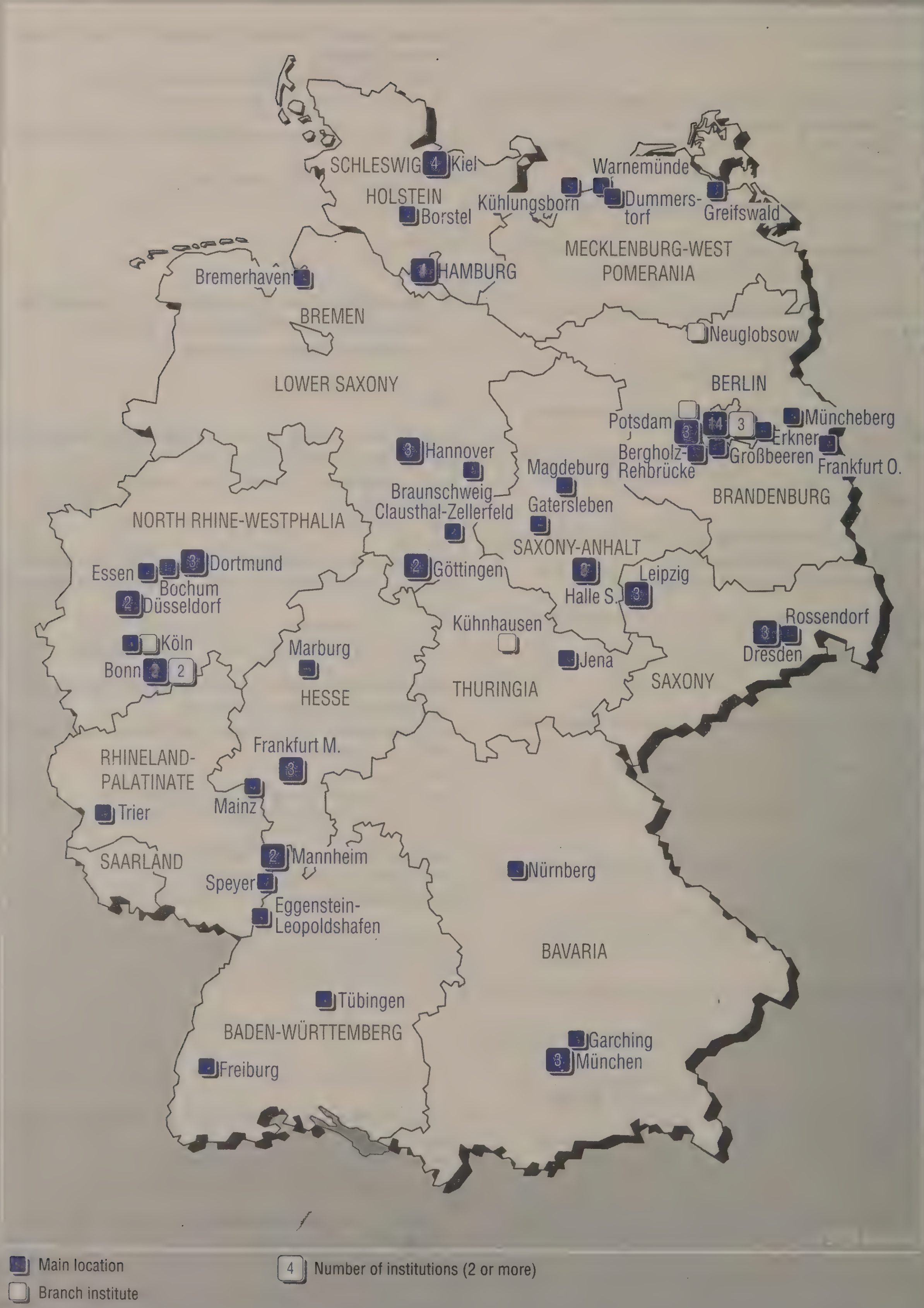
Bayern/Bavaria

Deutsche Forschungsanstalt für Lebensmittelchemie (DFA)
85748 Garching, Lichtenbergstraße 4
Tel.: 089/32091, Fax: 089/32094183

Deutsches Museum in München (DM)
80538 München, Museumsinsel 1
Tel.: 089/21791, Fax: 089/2179324

Germanisches Nationalmuseum (GNM)
90402 Nürnberg, Kartäusergasse 12
Tel.: 0911/13310, Fax: 0911/1331200

Locations of Blue List Institutions
in Germany



Source: BMBF (as of January 1996)

BMBF, BuFo '96

ifo Institut für Wirtschaftsforschung e. V. München (ifo)
81679 München, Poschingerstraße 5
Tel.: 0 89/92 24-0, Fax: 0 89/98 53 69

Institut für Zeitgeschichte (IfZ)
80636 München, Leonrodstraße 46 b
Tel.: 0 89/12 68 80, Fax: 0 89/1 23 17 27

Berlin

Deutsches Bibliotheksinstitut (DBI)
10559 Berlin, Alt Moabit 101 a
Tel.: 0 30/3 90 77-0, Fax: 0 30/3 90 77-1 00

Deutsches Institut für Wirtschaftsforschung (DIW)
14195 Berlin, Königin-Luise-Straße 5
Tel.: 0 30-8 97 89-0, Fax: 0 30/8 97 89-2 00

Deutsches Institut für Internationale Pädagogische Forschung (DIPF-Service)
10178 Berlin, Warschauer Straße 34-38
Tel.: 0 30/7 07 57 10, Fax: 0 30/7 07 57 16

Fachinformationszentrum Chemie GmbH (FIZ CH)
10587 Berlin, Franklinstraße 11
Tel.: 0 30/3 99 77-0, Fax: 0 30/3 99 77-1 14

Heinrich-Hertz-Institut für Nachrichtentechnik Berlin GmbH (HHI)
10587 Berlin, Einsteinufer 37
Tel.: 0 30/3 10 02-0, Fax: 0 30/3 10 02-2 13

Wissenschaftszentrum Berlin für Sozialforschung gGmbH (WZB)
10785 Berlin, Reichpietschufer 50
Tel.: 0 30/2 54 91-0, Fax: 0 30/25 49 16 84

Forschungsverbund Berlin e. V. (FVB)
12489 Berlin, Rudower Chaussee 5
Tel.: 0 30/63 92-33 60, Fax: 0 30/63 92-33 77

Ferdinand-Braun-Institut für Höchstfrequenztechnik (FBH)
im Forschungsverbund Berlin e. V.
12489 Berlin, Rudower Chaussee 5
Tel.: 0 30/63 92-26 01, Fax: 0 30/63 92-26 02

Forschungsinstitut für Molekulare Pharmakologie (FMP)
im Forschungsverbund Berlin e. V.
10315 Berlin-Friedrichsfelde, Alfred-Kowalke-Straße 4
Tel.: 0 30/5 16 30, Fax: 0 30/5 12 80 14

Weierstraß-Institut für Angewandte Analysis und Stochastik (WIAS)
im Forschungsverbund Berlin e. V.
10117 Berlin, Mohrenstraße 39
Tel.: 0 30/2 03 77-0, Fax: 0 30/2 00 49 75

Institut für Gewässerökologie und Binnenfischerei (IGB)
im Forschungsverbund Berlin e. V.
12587 Berlin, Müggelseedamm 310
Tel.: 0 30/64 18 16 02, Fax: 0 30/64 18 16 00

Institut für Kristallzüchtung (IKZ)
im Forschungsverbund Berlin e. V.
12489 Berlin, Rudower Chaussee 6
Tel.: 0 30/63 92-3 00, Fax: 0 30/63 92-30 03

Max-Born-Institut für Nichtlineare Optik und Kurzzeitspektroskopie (MBI)
im Forschungsverbund Berlin e. V.
12489 Berlin-Adlershof, Rudower Chaussee 6
Tel.: 0 30/63 92-13 01, Fax: 0 30/63 92-13 09

Institut für Zoo- und Wildtierforschung (IZW)
im Forschungsverbund Berlin e. V.
10315 Berlin, Alfred-Kowalke-Straße 17
Tel.: 0 30/5 16 81 01, Fax: 0 30/5 12 61 04

Paul-Drude-Institut für Festkörperelektronik (PDI)
im Forschungsverbund Berlin e. V.
10117 Berlin, Hausvogteiplatz 5–7
Tel.: 0 30/2 03 77-0, Fax: 0 30/2 03 77-2 01

Brandenburg

Astrophysikalisches Institut Potsdam (AIP)
14482 Potsdam, An der Sternwarte 16
Tel.: 03 31/74 99-0, Fax: 03 31/7 49 92 00

Deutsches Institut für Ernährungsforschung (DIFE)
14558 Bergholz-Rehbrücke, Arthur-Scheunert-Allee 114/116
Tel.: 03 32 00/88-0, Fax: 03 32 00/88-4 44

Zentrum für Agrarlandschafts- und Landnutzungsforschung e. V. (ZALF)
15374 Müncheberg, Eberswalder Straße 84
Tel.: 03 34 32/8 20, Fax: 03 34 32/8 22 12

Institut für Agrartechnik Bornim e. V. (ATB)
14469 Potsdam-Bornim, Max-Eyth-Allee 100
Tel.: 03 31/9 69 90, Fax: 03 31/9 69 98 49

Institut für Gemüse- und Zierpflanzenbau Großbeeren/Erfurt e. V. (IGZ)
14979 Großbeeren, Theodor-Echtermeyer-Weg 1
Tel.: 03 37 01/80, Fax: 03 37 01/3 91

Institut für Halbleiterphysik (IHP) Frankfurt/Oder GmbH
15230 Frankfurt/Oder, Walter-Korsing-Straße 2
Tel.: 03 35-56 25-0, Fax: 03 35-56 25-33

Institut für Regionalentwicklung und Strukturplanung e. V. (IRS)
15537 Erkner, Flakenstraße 28–31
Tel.: 0 33 62/7 93-1 30, Fax: 0 33 62/7 93-1 11

Potsdam-Institut für Klimafolgenforschung e. V. (PIK)
14473 Potsdam, Telegrafenberg
Tel.: 03 31/2 88-0, Fax: 03 31/2 88-26 00

Bremen

Deutsches Schiffahrtsmuseum (DSM)
27568 Bremerhaven, Van-Ronzelen-Straße
Tel.: 04 71/48 20 70, Fax: 04 71/4 82 07 55

Hamburg

Bernhard-Nocht-Institut für Tropenmedizin (BNI)
20359 Hamburg, Bernhard-Nocht-Straße 74
Tel.: 0 40/3 11 82-0, Fax: 0 40/3 11 82-4 00

Deutsches Übersee-Institut (DÜI)
20354 Hamburg, Neuer Jungfernstieg 21
Tel.: 0 40/3 56 25 93, Fax: 0 40/3 56 25 47

Heinrich-Pette-Institut für Experimentelle Virologie und Immunologie (HPI) an der Universität Hamburg
20251 Hamburg, Martinistraße 52
Tel.: 0 40/4 80 51-0, Fax: 0 40/46 47 09

HWWA-Institut für Wirtschaftsforschung Hamburg (HWWA)
20354 Hamburg, Neuer Jungfernstieg 21
Tel.: 0 40/35 62-0, Fax: 0 40/35 19 00

Hessen/Hesse

Deutsches Institut für Internationale Pädagogische Forschung (DIPF)
60486 Frankfurt/M., Schloßstraße 29
Tel.: 0 69/77 02 45, Fax: 0 69/70 82 28

Forschungsinstitut und Naturmuseum Senckenberg (FIS)
60325 Frankfurt, Senckenberganlage 25
Tel.: 0 69/75 42-0, Fax: 0 69/74 62 38

Herder-Institut e. V (HI)
35037 Marburg, Gisonenweg 5-7
Tel.: 0 64 21/1 84-0, Fax: 0 64 21/1 84-1 39

Deutsches Institut für Erwachsenenbildung Pädagogische Arbeitsstelle des Deutschen Volkshochschul-Verbandes e. V. (DIE/DVV)
60322 Frankfurt/M., Holzhausenstraße 21
Tel.: 0 69/15 40 05-0, Fax: 0 69/15 40 05-74

Mecklenburg-Vorpommern/West Pomerania

Institut für Atmosphärenphysik an der Universität Rostock (IAP)
18221 Kühlungsborn, Schloßstraße 4-6
Tel.: 03 82 93/6 80, Fax: 03 82 93/68 50

Forschungsinstitut für die Biologie landwirtschaftlicher Nutztiere, Dummerstorf (FBN)
18196 Dummerstorf, Wilhelm-Stahl-Allee 2
Tel.: 03 82 08/6 85, Fax: 03 82 08/6 86 02

Institut für Niedertemperaturplasmaphysik e. V. an der Ernst-Moritz-Arndt-Universität Greifswald (INP)
17489 Greifswald, Robert-Blum-Straße 8-10
Tel.: 0 38 34/5 54-3 00, Fax: 0 38 34/5 54-3 01

Institut für Ostseeforschung an der Universität Rostock (IOW)
18119 Warnemünde, Seestraße 15
Tel.: 03 81/5 19 70, Fax: 03 81/51 97 48 40

Niedersachsen/Lower Saxony

Akademie für Raumforschung und Landesplanung (ARL)
30161 Hannover, Hohenzollernstraße 11
Tel.: 05 11/3 48 42-0, Fax: 05 11/3 48 42-41

Deutsches Primatenzentrum GmbH (DPZ)
37077 Göttingen, Kellnerweg 4
Tel.: 05 51/38 51-0, Fax: 05 51/38 51-2 28

Institut für den Wissenschaftlichen Film gGmbH (IWF)
37075 Göttingen, Nonnenstieg 72
Tel.: 05 51/2 02, Fax: 05 51/20 22 00

Institut für Erdöl- und Erdgasforschung (IfE)
38678 Clausthal-Zellerfeld, Walther-Nernst-Straße 7
Tel.: 0 53 23/7 11-0, Fax: 0 53 23/7 11-2 00

Niedersächsisches Landesamt für Bodenforschung – Geowissenschaftliche Gemeinschaftsaufgaben (NLfB-GGA)
30655 Hannover, Stilleweg 2
Tel.: 05 11/6 43-34 96, Fax: 05 11/6 43-23 04

Technische Informationsbibliothek Hannover (TIB)
30167 Hannover, Welfengarten 1B
Tel.: 05 11/7 62-22 68, Fax: 05 11/7 62-26 86

DSMZ - Deutsche Sammlung von Mikroorganismen und Zellkulturen GmbH
38124 Braunschweig, Mascheroder Weg 1B
Tel.: 05 31/26 16-0, Fax: 05 31/26 16-4 18

Nordrhein-Westfalen/North Rhine-Westphalia

Deutsches Bergbau-Museum Bochum (DBM)
44791 Bochum, Am Bergbaumuseum 28
Tel.: 02 34/5 87 70, Fax: 02 34/5 87 71 11

Diabetes-Forschungsinstitut an der Heinrich-Heine-Universität Düsseldorf (DFI)
40225 Düsseldorf, Auf'm Hennekamp 65
Tel.: 02 11/33 82-1, Fax: 02 11/33 82-6 03

Forschungsinstitut für Kinderernährung (FKE)
44225 Dortmund (Brünninghausen), Heinstück 11
Tel.: 02 31/71 40 21, Fax: 02 31/71 15 81

Institut für Arbeitsphysiologie an der Universität Dortmund (IFA)
44139 Dortmund, Ardeystraße 67
Tel.: 02 31/10 84-2 05, Fax: 02 31/10 84-3 08

Institut für Spektrochemie und angewandte Spektroskopie (ISAS)
44139 Dortmund, Bunsen-Kirchhoff-Straße 11
Tel.: 02 31/13 92-0, Fax: 02 31/13 92-1 20

Medizinisches Institut für Umwelthygiene (MIU)
an der Heinrich-Heine-Universität Düsseldorf
40225 Düsseldorf, Auf'm Hennekamp 50
Tel.: 02 11/3 38 90, Fax: 02 11/3 19 09 10

Rheinisch-Westfälisches Institut für Wirtschaftsforschung (RWI)
45128 Essen, Hohenzollernstraße 1-3
Tel.: 02 01/81 49-0, Fax: 02 01/81 49-2 00

Zentralbibliothek der Landbauwissenschaften (ZBL)
53115 Bonn, Nußallee 15 a
Tel.: 02 28/73 34 02, Fax: 02 28/73 32 81

Deutsche Zentralbibliothek der Medizin (ZBM)
50931 Köln, Joseph-Stelzmann-Straße 9
Tel.: 02 21/4 78 56 00, Fax: 02 21/4 78 56 97

Zoologisches Forschungsinstitut und Museum Alexander Koenig (ZFMK)
53113 Bonn, Adenauerallee 162
Tel.: 02 28/9 12 22 00, Fax: 02 28/21 69 79

Rheinland-Pfalz/Rhineland-Palatinate

Forschungsinstitut für öffentliche Verwaltung (FÖV)
bei der Hochschule für Verwaltungswissenschaften Speyer
67324 Speyer, Freiherr-vom-Stein-Straße 2
Tel.: 0 62 32/6 54-3 86, Fax: 0 62 32/6 54-2 08

Römisch-Germanisches Zentralmuseum (RGZM) – Forschungsinstitut für Vor- und Frühgeschichte
55116 Mainz, Ernst-Ludwig-Platz 2
Tel.: 0 61 31/23 22 31, Fax: 0 61 31/23 22 35

Zentralstelle für Psychologische Information und Dokumentation (ZPID) an der Universität Trier
54286 Trier, Postfach 38 25
Tel.: 06 51/2 01-28 77, Fax: 06 51/2 01-20 71

Sachsen/Saxony

Forschungszentrum Rossendorf e. V. (FZR)
01314 Dresden, Postfach 51 01 19
Tel.: 03 51/5 91-0, Fax: 03 51/3 60 69

Institut für Festkörper- und Werkstofforschung Dresden e. V. (IFW)
01069 Dresden, Helmholtzstraße 20
Tel.: 03 51/4 65 93 80, Fax: 03 51/4 65 95 00

Institut für Länderkunde (IfL)
04329 Leipzig, Schongauerstraße 9
Tel.: 03 41/2 55 65 00, Fax: 03 41/2 55 65 98

Institut für Oberflächenmodifizierung e. V. (IOM)
04318 Leipzig, Permoserstraße 15
Tel.: 03 41/2 35-0, Fax: 03 41/23 92 23 13

Institut für ökologische Raumentwicklung e. V. Dresden (IÖR)
01217 Dresden, Weberplatz 1
Tel.: 03 51/4 67 90, Fax: 03 51/4 67 92 12

Institut für Polymerforschung Dresden e. V. (IPF)
01069 Dresden, Hohe Straße 6
Tel.: 03 51/46 58-0, Fax: 03 51/46 58-2 14/2 84

Institut für Troposphärenforschung e. V. (IfT)
04318 Leipzig, Permoserstraße 15
Tel.: 03 41/2 35 20, Fax: 03 41/2 35 23 61

Sachsen-Anhalt/Saxony-Anhalt

Institut für Neurobiologie Magdeburg (IfN)
39118 Magdeburg, Brenneckestraße 6
Tel.: 03 91/6 26 32 18, Fax: 03 91/61 61 60

Institut für Pflanzenbiochemie (IPB)
06120 Halle/Saale, Weinberg 3
Tel.: 03 45/60 13 12, Fax: 03 45/65 16 49

Institut für Pflanzengenetik und Kulturpflanzenforschung (IPK)
06466 Gatersleben, Corrensstraße 3
Tel.: 03 94 82/53 27, Fax: 03 94 82/52 86

Institut für Wirtschaftsforschung Halle (IWH)
06116 Halle, Delitzscher Straße 118
Tel.: 03 45/77 53 60, Fax: 03 45/7 75 38 20

Institut für Agrarentwicklung in Mittel- und Osteuropa (IAMO)
06112 Halle (Saale), Magdeburger Straße 1
Tel.: 03 45/5 00 81 11, Fax: 03 45/5 12 65 99

Schleswig-Holstein

Forschungsinstitut Borstel (FIB)
Institut für Experimentelle Biologie und Medizin
23845 Borstel, Parkallee 11
Tel.: 0 45 37/10-0, Fax: 0 45 37/10-2 44

Institut für die Pädagogik der Naturwissenschaften (IPN)
an der Universität Kiel
24105 Kiel, Olshausenstraße 62
Tel.: 04 31/8 80 00, Fax: 04 31/8 80 15 21

Institut für Meereskunde an der Universität Kiel (IfM)
24105 Kiel, Düsternbrooker Weg 20
Tel.: 04 31/5 97-0, Fax: 04 31/56 58 76

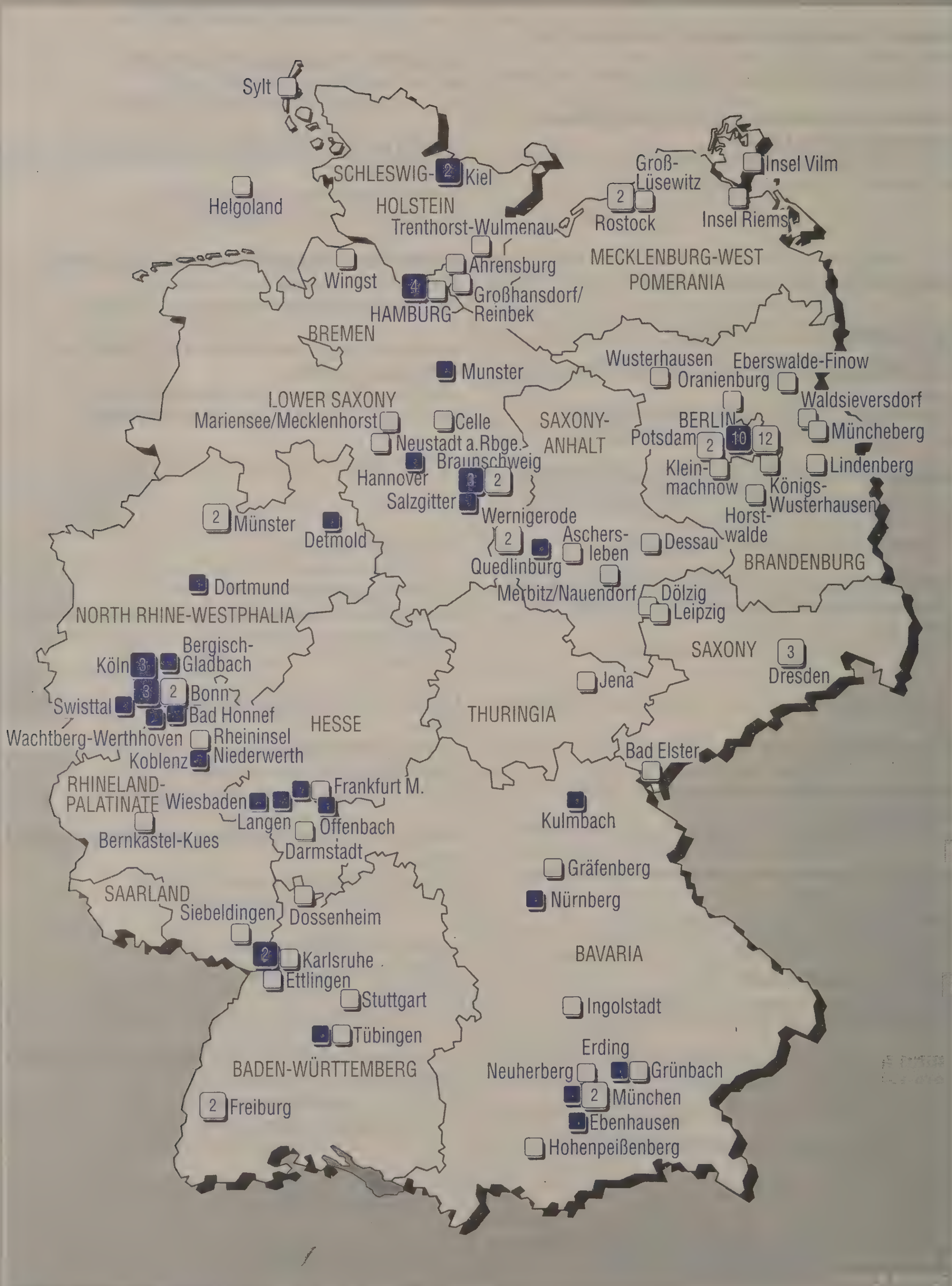
Institut für Weltwirtschaft (IfW)
an der Universität Kiel
24105 Kiel, Düsternbrooker Weg 120
Tel.: 04 31/88 14-1, Fax: 04 31/8 81 45 00

Zentralbibliothek der Wirtschaftswissenschaften (ZBW)
24105 Kiel, Düsternbrooker Weg 120
Tel.: 04 31/88 14-1, Fax: 04 31/8 81 45 00

Thüringen/Thuringia

Institut für Molekulare Biotechnologie e. V. Jena (IMB)
07745 Jena, Beutenbergstraße 11
Tel.: 0 36 41/85 22 00, Fax: 0 36 41/85 22 03

Locations of federal institutions performing R&D



Main location

Branch institute

4 Number of institutions (2 or more)

Source: BMBF (as of January 1996)

BMBF, BuFo '96

5. Federal institutions performing R&D

Area of responsibility of the Federal Chancellery

Stiftung Wissenschaft und Politik (SWP)
82067 Ebenhausen, Zellerweg 27
Tel.: 0 81 78/7 00, Fax: 0 81 78/7 03 12

Area of responsibility of the Federal Foreign Office

Deutsches Archäologisches Institut (DAI)
14195 Berlin, Podbielskiallee 69-71
Tel.: 0 30/8 30 08-0, Fax: 0 30/83 00 81 08

Area of responsibility of the Federal Ministry of the Interior

Institut für Angewandte Geodäsie (IfAG)
60598 Frankfurt/M., Richard-Strauss-Allee 11
Tel.: 0 69/6 33 31, Fax: 0 69/6 33 34 25

Bundesinstitut für ostwissenschaftliche und internationale Studien (BIOst)
50823 Köln, Lindenbornstraße 22
Tel.: 02 21/5 74 70, Fax: 02 21/5 74 71 10

Bundesinstitut für Bevölkerungsforschung (BIB)
65189 Wiesbaden, Gustav-Stresemann-Ring 6
Tel.: 06 11/7 51, Fax: 06 11/72 40 00

Bundesinstitut für Sportwissenschaften (BISp)
50933 Köln, Carl-Diem-Weg 4
Tel.: 02 21/49 79-0, Fax: 02 21/49 51 64

Area of responsibility of the Federal Ministry of Economics

Physikalisch-Technische Bundesanstalt (PTB)
38116 Braunschweig, Bundesallee 100
Tel.: 05 31/5 92-0, Fax: 05 31/5 92-40 06

Bundesanstalt für Materialforschung und -prüfung (BAM)
12205 Berlin, Unter den Eichen 87
Tel.: 0 30/81 04-0, Fax: 0 30/8 11 20 29

Bundesanstalt für Geowissenschaften und Rohstoffe (BGR)
30655 Hannover, Stilleweg 2
Tel.: 05 11/6 43-0, Fax: 05 11/6 43-23 04

Area of responsibility of the Federal Ministry of Food, Agriculture and Forestry

Bundesforschungsanstalt für Landwirtschaft Braunschweig-Völkenrode (FAL)
38116 Braunschweig, Bundesallee 50
Tel.: 05 31/59 61, Fax: 05 31/59 68 14

Biologische Bundesanstalt für Land- und Forstwirtschaft Berlin/Braunschweig (BBA)
38104 Braunschweig, Messeweg 11/12
Tel.: 05 31/29 95, Fax: 05 31/2 99 30 00

Bundesanstalt für Milchforschung (BAM)
24103 Kiel, Hermann Weigmannstraße 1
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Abbreviation

AFO	Contract Research and Development East
AIDS	Acquired Immune Deficiency Syndrome
AiF	Confederation of Industrial Research Associations (Arbeitsgemeinschaft Industrieller Forschungsvereinigungen „Otto von Guericke“ e. V., Köln)
ART	Artificial Intelligence
ATV	Automated Transfer Vehicle
AWI	Institute for Polar and Marine Research
AWO	Contract Research and Development West-East
BAM	Federal Institute of Materials Research and Testing
BAW	Federal Institute for Waterway Engineering (Bundesanstalt für Wasserbau, Karlsruhe)
BGR	Federal Institute for Geosciences and Raw Materials (Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover)
BJTU	Direct-investment capital for young technology-based companies
BLK	Federal/Länder Commission for Educational Planning and Research Promotion (Bund-Länder-Kommission für Bildungsplanung und Forschungsförderung, Bonn)
BMA	Federal Ministry of Labour and Social Affairs (Bundesministerium für Arbeit und Sozialordnung)
BMBau	Federal Ministry for Regional Planning, Building and Urban Development (Bundesministerium für Raumordnung, Bauwesen und Städtebau)
BMBF	Federal Ministry of Education, Science, Research and Technology (Bundesministerium für Bildung, Wissenschaft, Forschung und Technologie)
BMG	Federal Ministry of Health (Bundesministerium für Gesundheit)
BMU	Federal Ministry for Environment, Nature Conversation and Reactor Safety (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit)
BMV	Federal Ministry of Transport (Bundesministerium für Verkehr)
BMVg	Federal Ministry of Defence Bundesministerium der Verteidigung)
BMWi	Federal Ministry of Economics (Bundesministerium für Wirtschaft)
BMZ	Federal Ministry for Economic Cooperation (Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung)
BTU	Direct-investment capital for small technology-based companies
CEC	Commission of the European Community
CEO	Centers of Earth Observation
CERN	Conseil Europeenne pour la Recherche Nucleaire, Genf
COF	Columbus Orbital Facility
COST	Cooperation Europeenne dans le domaine de la recherche scientifique et technique
CREST	Scientific and Technical Research Committee
DARA	German Space Agency (Deutsche Agentur für Raumfahrtangelegenheiten GmbH, Bonn)
DEKORP	German Continental Reflection Seismic Programme
DESY	Stiftung Deutsches Elektronen-Synchrotron, Hamburg
DFG	German Research Foundation (Deutsche Forschungsgemeinschaft e. V., Bonn)
DFKI	German Artificial Intelligence Research Centre (Deutsches Forschungszentrum für Künstliche Intelligenz, Kaiserslautern)
DFN	Association for the Promotion of a German Research Network (Deutsches Forschungsnetz)
DIJ	German Institute for Japanese Studies
DIKHUT	German-Israeli Cooperation Council for High and Environmental Technologies
DIW	German Institute for Economic Research (Deutsches Institut für Wirtschaftsforschung, Berlin)
DKRZ	German Climate Computer Centre (Deutsches Klimarechenzentrum, Hamburg)
DLR	German Aerospace Research Establishment (Deutsche Forschungsanstalt für Luft- und Raumfahrt e. V., Köln-Porz)

EASDAQ	European Association of Securities Dealers Automated Quotation System
EDP	Electronic Data Processing
EEA-states	Norway, Iceland, Liechtenstein
ELDORADO	ELDORADO Wind and ELDORADO Sun programmes
EMBC	European Molecular Biology Conference, Heidelberg
EMBL	European Molecular Biology Laboratory, Heidelberg
ERP	European Recovery Programme
ERS	European Earth Resources Satellite
ESA	European Space Agency, Paris
ESO	European Southern Observatory, Garching
ESRF	European Synchrotron Radiation Facility, Grenoble
EU	European Union
EURATOM	European Atomic Energy Community
EUREKA	European Retrievable Carrier
EUROMIR '94	30-day space mission
EUROTRAC	European Experiment on the Transport and Transformation of Environmentally Relevant Trace Constituents in the Troposphere over Europe

FhG	Fraunhofer Society (Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e. V., München)
FTE	Full-time equivalent

GATT	General Agreement on Tarifs and Trade
GBF	National Research Centre for Biotechnological Research (Gesellschaft für Biotechnologische Forschung mbH, Braunschweig-Stöckheim)
GDP	Gross domestic product
GDR	German Democratic Republic
GERD	Gross domestic expenditure on R&D
GESIS	Gesellschaft Sozialwissenschaftlicher Infrastruktureinrichtungen e. V., München
GFZ	Geoscientific Research Centre (GeoForschungsZentrum Potsdam)
GNP	Gross national product
GOOS	Global Ocean Observing System
G7-states	USA, Japan, Canada, France, Italy, UK, Germany

HCM	Human Capital and Mobility
HEP	University Renewal Programme (Hochschulerneuerungsprogramm)
HERA	Hadron Elektron Ring Accelerator
HFSP	Human Frontier Science Programme
HGF	Hermann von Helmholtz Association of German Research Centres
HIS	Higher Education Information System
HSP	Special University Programme (Hochschulsonderprogramm)

IAEA	International Atomic Energy Agency
ICE	High-speed train
IEA	International Energy Agency, Paris
IGFA	International Group of Funding Agencies for Global Change Research
IIASA	International Institute for Applied Systems Research, Laxenburg (Österreich)
IID	German Information Society Initiative
ILL	Institute Max von Laue – Paul Langevin, Grenoble
INSTI	Stimulating innovation in German industry by providing scientific and technical information (Innovationsstimulierung der deutschen Wirtschaft durch wissenschaftlich-technische Information)
INTAS	Independent states of the Former Soviet Union
INTELSAT	Communication satellite
ISETEC	Innovative sea port technologies
ITER	International Thermonuclear Experimental Reactor
ITU	International Telecommunication Union

JESSI	Joint European Submicron Silicon Initiative
JGOFS	Joint Global Ocean Flux Study
JRC	Joint Research Centre
KMK	The Conference of the Ministers of Education (Kultusministerkonferenz)
KOSEF	Korea Science and Engineering Foundation
KTB	Continental Deep Drilling Programme of the Federal Republik of Germany (Kontinentales Tiefbohrprogramm)
KUSTOS	Cooperative research project on Near-Shore Flows of Substances and Energy
LASER	Light Amplification Stimulated Emission Radiation
LEONARDO	EU programme in education
LHC	Large Hadron Collider
MIKUM	Pilot project supporting access to data bases by SMEs
MIR	space mission
MOTIV	Mobilitiy and Transport in Intermodal Traffic
MPG	Max Planck Society (Max-Planck-Gesellschaft zur Förderung der Wissenschaften e. V., München)
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization, Brüssel
NEA	Nuclear Energy Agency, Paris
NICs	Newly Industrialised Countries
NTBFs	New Technology-Based Firms
OECD	Organization for Economic Cooperation and Development, Paris
OPEC	Organization of Petroleum Exporting Countries
ORFEUS	Orbiting and Retrivable far and extreme ultraviolet spectrometers
OTA	Office of Technology Assessment
PC	Personal Computer
PTB	Federal Institute of Physics and Metrology (Physikalisch-Technische Bundesanstalt, Braunschweig)
PIUS	Production-Integrated Environmental Protection (Produkt- und Produktionsintegrierter Umweltschutz)
R&D	Research and Development
ROSAT	satellite
R&T	Research and Technology
SAG	Space Advisory Group
SMEs	Small and medium-sized enterprises
SOKRATES	EU programme in education
SPAS	Shuttle Pallet Satellite
SPRINT	Strategie Programme for Innovation and Technology Transfer
STN	Scientific and Technical Network, Columbus/Ohio, USA
TA	Technology Assessment
THERMIE	Energy demonstrations programme
TIB	Technische Informationsbibliothek Hannover
TRANSRAPID	Magnetic levitation line

UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNESCO	United Nations Educational, Scientific and Cultural Organization, Paris
UV	Ultraviolet rays
VLT	Very Large Telescope
WBGU	German Advisory Council on Global Change (Wissenschaftlicher Beirat Globale Umweltveränderung)
WCRP	World Climate Research Programme
WHO	World Health Organization, Genf
WIPO	World Intellectual Property Organization
WOCE	World Ocean Circulation Experiment
WTO	World Tourism Organization

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